

MULTILAYERED (Hg,Cd)Te INFRARED DETECTOR

Final Technical Report

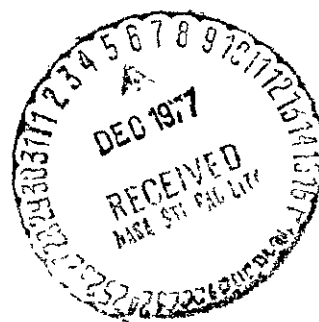
Prepared for

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

(NASA-CR-151548) MULTILAYERED (Hg,Cd)Te INFRARED DETECTOR Final Technical Report (Honeywell Radiation Center) 63 p HC A04/HF A01	CSCL 20F	N78-11453 Unclas 53531
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Contract NAS9-14180, Modification 7S
May 16, 1977

HONEYWELL
Radiation Center
2 Forbes Road
Lexington, Massachusetts 02173



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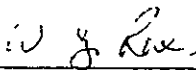
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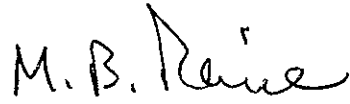
May 16, 1977

Prepared by:

Approved by:



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FOREWORD

This is the final technical report for the program "Multilayered (Hg,Cd)Te Infrared Detector", NASA Contract NAS9-14180, Modification 7S. This program was performed at the Honeywell Radiation Center during the period from July, 1973, through May, 1977. This report covers the period from April 30, 1975, through April 18, 1977.

The Project Engineer during the period of this report was Mr. William G. Rae and the Program Manager was Dr. Marion B. Reine. The Technical Monitor for this program at NASA Johnson Space Center was Dr. F.L. Baiamonte.

ACKNOWLEDGEMENTS

The technical assistance of Mr. Brian W. Denly in fabricating the three-color detectors described in this report is greatly appreciated. Mr. Robert F. Bauer assisted in the formulation of the process used. The three-channel preamplifier unit was redesigned by Mr. A.R. Gunion, and Mr. P.T. MacLearn assisted in the construction and testing of this unit. Mr. T.T.S. Wong assisted in analyzing the final test data.

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

The overall goal of this program was to develop multilayered mercury-cadmium telluride (HgCdTe, (Hg,Cd)Te or $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$) photoconductive detectors capable of providing individual coverage of three separate spectral wavelength bands without the use of beam splitters.

Such a multilayered "three-color" detector on a single dewar could in principle take the place of three separate detector/filter/dewar units and thus enable simpler and more reliable mechanical and optical designs for NASA multispectral scanners and radiometers.

Phase I of this program (extending from July 1974 through May 1975) developed the first operational three-color HgCdTe photoconductive detector module for coverage of the $1\text{ }\mu\text{m} - 3\text{ }\mu\text{m}$, $3\text{ }\mu\text{m} - 4.8\text{ }\mu\text{m}$ and $5\text{ }\mu\text{m} - 11\text{ }\mu\text{m}$ spectral bands. Prior to this Phase I program, multilayered HgCdTe detectors had been designed and fabricated only for two-color operation and consisted of two individual HgCdTe detectors in a layer configuration with the shorter wavelength detector mounted on top of the longer wavelength detector.

Detectivities (at 10 kHz) achieved in this first three-color detector unit, operating at 77°K were $1.4 \times 10^{11}\text{ cm-Hz}^2/\text{W}$ at $2.9\text{ }\mu\text{m}$ (Channel 1), $3.9 \times 10^{10}\text{ cm-Hz}^2/\text{W}$ at $6.0\text{ }\mu\text{m}$, (Channel 2), and $3.0 \times 10^{10}\text{ cm-Hz}^2/\text{W}$ at $11.4\text{ }\mu\text{m}$ (Channel 3). The relative spectral response data for this three-color detector module are shown in Figure 1.1. This three-color detector unit (Model Number LK193A1-S/N-U1) was delivered to NASA Johnson Space Center in a metal liquid-nitrogen dewar, along with a three-channel preamplifier assembly. The test report for this first three-color detector is included in this report as Appendix A.

The goal of Phase II of this program was to further develop multilayered three color HgCdTe detector modules which covered spectral bands in the $8\text{--}14\text{ }\mu\text{m}$ spectral range. The specific design goals for this phase of the program were the following:

WAVELENGTH CHANNEL (MICROMETERS)	DETECTIVITY ($\text{cm-Hz}^2/\text{Watt}$)
10.1 - 11.0	1×10^{10}
11.0 - 12.0	1×10^{10}
12.0 - 13.0	1×10^{10}

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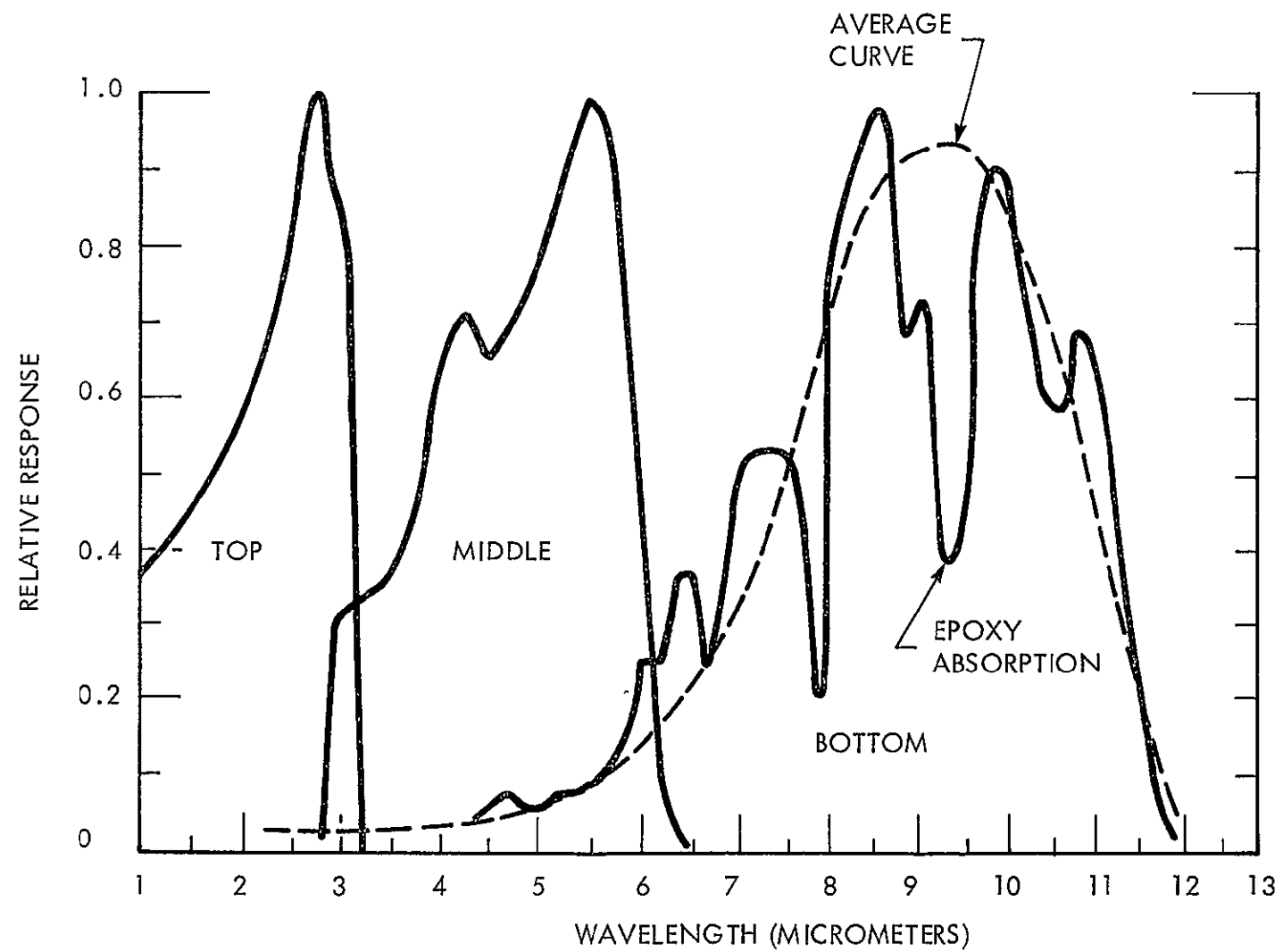


Figure 1.1 RELATIVE SPECTRAL RESPONSE FOR THE HgCdTe THREE-COLOR DETECTOR UNIT LK193A1-S/N-U1.

Development of a three-color detector module with these design goals entailed the following two additional problem areas:

1. the narrow spectral bands required much more careful selection and prefabrication testing of the $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ material used for the top and middle detectors;
2. an epoxy bonding layer had to be found which had good infrared transmission properties in the 11.0 - 13.0 μm range and which was also chemically and mechanically compatible with HgCdTe processing techniques.

A substantial effort was devoted to selection and characterization of the $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ material for the top and middle detectors. The $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ alloy composition requirements for the narrow spectral ranges are discussed in Section 2.3. A non-destructive testing (NDT) technique was used to actually measure the photoconductive response versus wavelength for HgCdTe wafers prior to their fabrication into detectors.

One of the major tasks in Phase II of this program was to survey, examine and select suitable bonding layers for the three-layer fabrication which would be highly transmissive in the 11.0-13.0 μm wavelength range and which also would be thermally, chemically, mechanically and electrically compatible with the HgCdTe fabrication processing used. The data for the Phase I threecolor detector module (shown in Figure 1.1) indicated pronounced epoxy absorption bands at around 8 μm , 9.2 μm , and at 10.4 μm , but gave no information beyond about 11 μm . A total of six candidate bonding materials was surveyed and transmission data over the 8.0-14.0 μm range were taken on samples of each material. These data are discussed in Section 2.4 of this report.

SECTION 2

THREE-COLOR DETECTOR MODULE DESIGN AND FABRICATION

2.1 DESCRIPTION OF THE MULTILAYERED THREE-COLOR DETECTOR MODULE

The detector module consists of three single elements constructed sequentially in the form of a sandwich as shown in Figure 2.1. The top detector is designed to operate from 10.1 to 11.0 μm wavelength and act as an optical filter to the detectors immediately below. The back of the detector is antireflection (A-R) coated with zinc sulphide to optimize transmission in the wavelength region 11 μm to 13 μm , and to provide some form of insulation to the detector immediately below.

The middle detector is designed to operate over the wavelength region 11.0 μm to 12.0 μm . The detector has an A-R coating of zinc sulphide applied to the front surface to optimize the transmission into the detector and the back of this detector has an A-R coating of ZnS applied to optimize transmission of infrared energy in the 12 μm to 13 μm region of the spectrum.

The bottom detector is optimized for operation from 12.0 μm to 13.0 μm with an A-R coating of ZnS applied to the front surface of the detector.

All three detectors are bonded together with an epoxy called Epoxy A. This epoxy was chosen from several different epoxies studied in the program because of its good transmission properties in the 10.1 to 13.2 μm region of the infrared spectrum.

2.2 DETECTOR MODULE FABRICATION

2.2.1 Bottom Detector

The bottom detector is fabricated first. A slab of HgCdTe material is lapped and chemically etched and then is bonded to an Irtran substrate with Epoxy A. The slab is then lapped and etched to a thickness of 10 μm . The detectors are delineated using photolithographic techniques. Contacts are applied by evaporating metal through a metal mask. An anti-reflection coating of zinc sulphide is applied to the detector surface.

2.2.2 Middle Detector

A second slab of HgCdTe material of the required wavelength is lapped and chemically etched. This slab then has a coating of zinc sulphide of the necessary thickness applied by evaporation techniques to one surface.

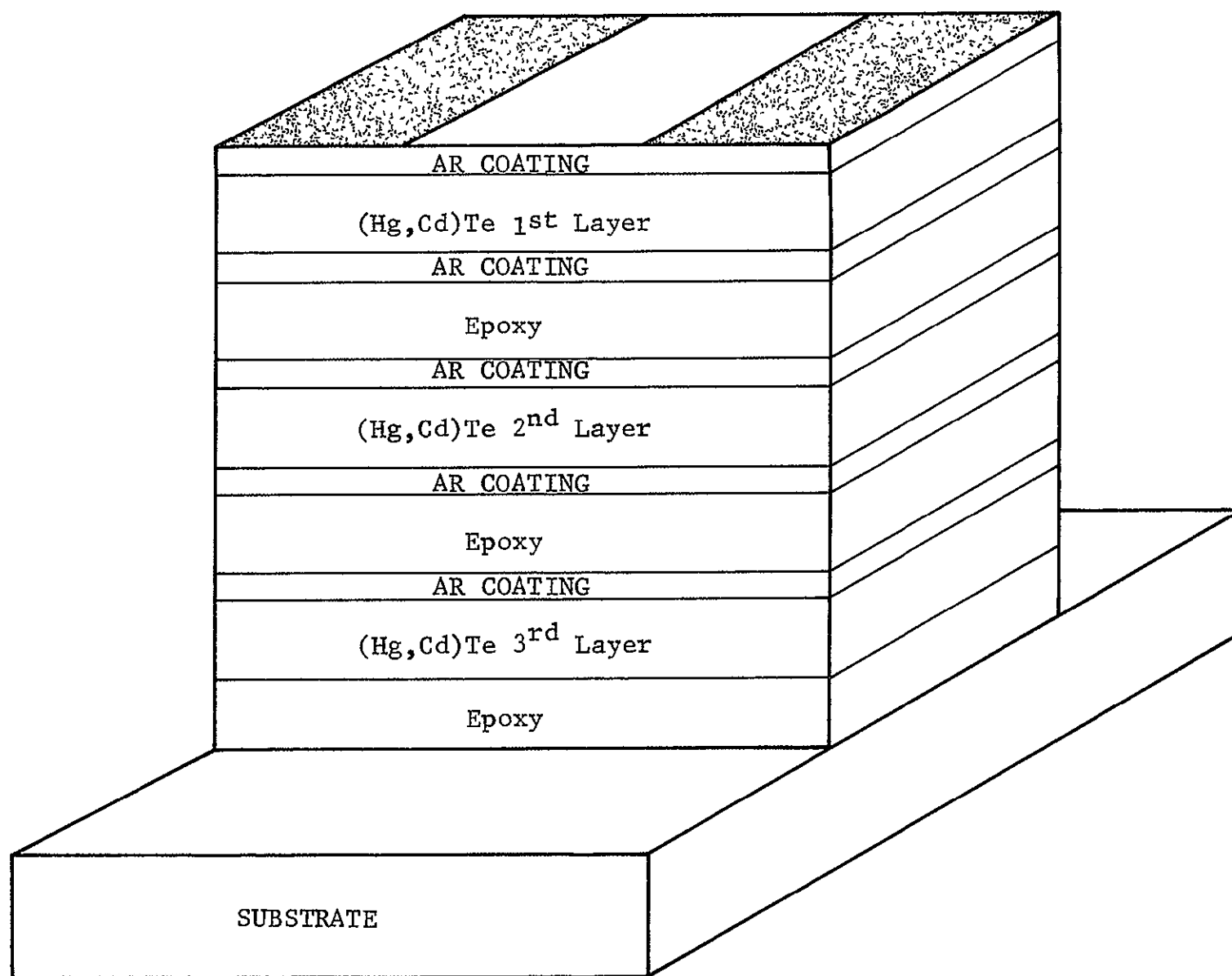


Figure 2.1 MULTILAYERED DETECTOR

This surface then is bonded using Epoxy A to the detector fabricated in 2.2.1. The process of thinning is then repeated, and the middle detector is finally delineated using a photolithographic process. Contacts are applied as before, and an anti-reflection coating is applied.

2.2.3 Top Detector

The top detector is fabricated in a similar fashion as described in 2.2.2. When the total module has completed the standard processing cycle, contact leads are thermo-compression bonded to the contact pad on each detector.

The three-layer detector module is then assembled into a field-of-view (FOV) housing. Over the aperture of the FOV is placed a germanium filter which passes energy between 10.3 to 13.2 μm . The FOV housing is assembled into a long hold-time liquid-nitrogen metal dewar (KD-101).

2.3 HgCdTe ALLOY COMPOSITION REQUIREMENTS

$\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ is a ternary alloy semiconductor with a direct energy band gap E_g which depends on alloy composition (i.e., the relative amounts of Hg and Cd) and on temperature. The cutoff wavelength λ_{co} of a photoconductive $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ detector is related to the band gap energy E_g :

$$\lambda_{\text{co}} = \frac{1.24}{E_g} \quad (1)$$

where λ_{co} is in micrometers (μm) and E_g is in electron volts (eV). The relationship between E_g and alloy composition x and absolute temperature T is given by:

$$E_g = 1.59x - 0.25 + 5.233 (10^{-4})T(1 - 2.08x) + 0.327x^3 \quad (2)$$

The cut-off wavelength λ_{co} for $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$, as determined from Equations 1 and 2, is shown in Figure 2.2 as a function of temperature.

This relationship was used to determine the alloy composition values required for the top, middle and bottom detector elements in the long wavelength three color detector module.

For this program, cutoff wavelengths at 77°K of 11.0 μm , 12.0 μm and 13 μm were required. Alloy compositions corresponding to cutoff wavelengths

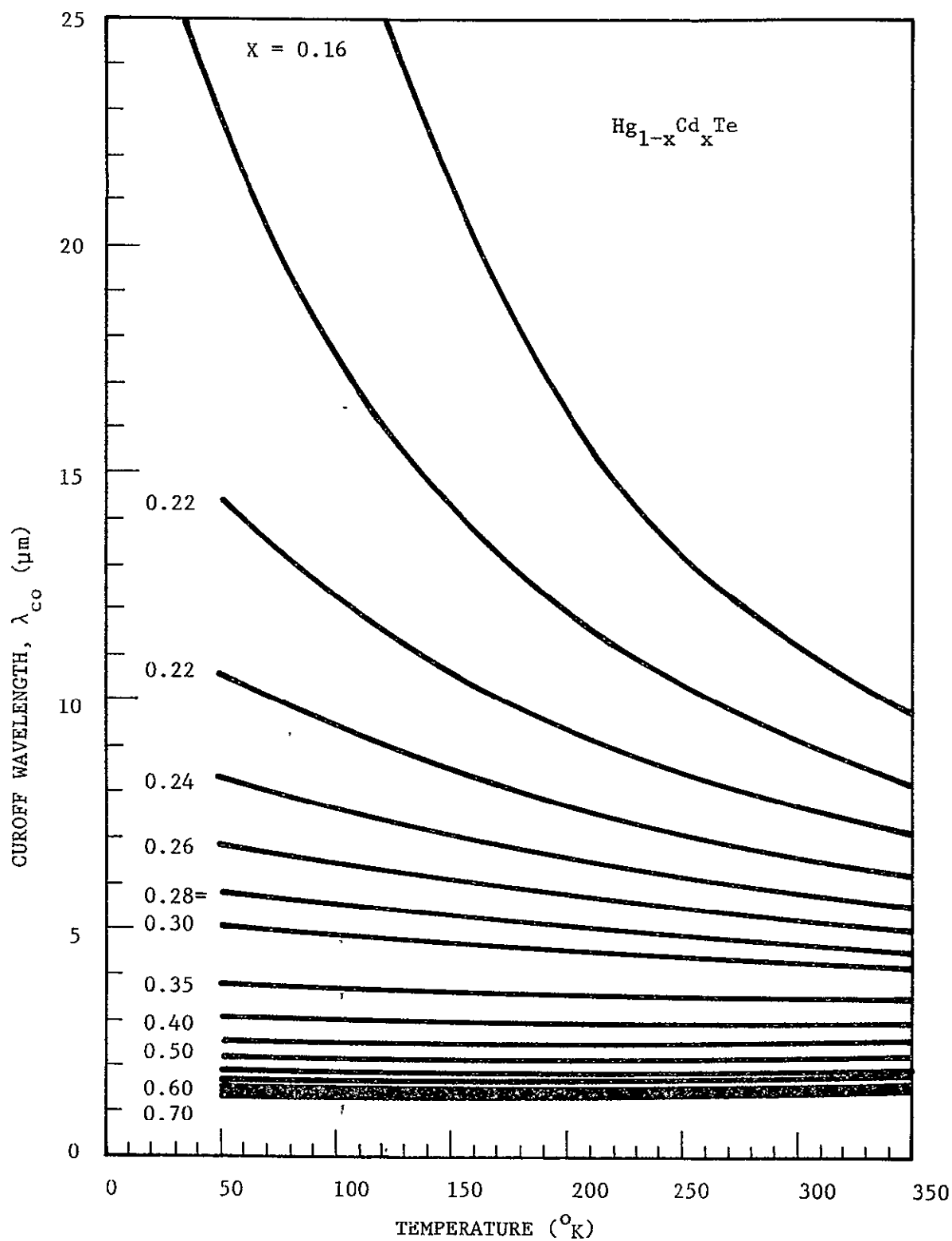


Figure 2.2 CUTOFF WAVELENGTH FOR $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ AS A FUNCTION OF TEMPERATURE AND ALLOY COMPOSITION (FROM J.L. SCHMIT AND E.L. STELZER, J. APPL. PHYS. 40: 4865 (1969))

around these values (taken from Equations 1 and 2) are tabulated below:

CUTOFF WAVELENGTH At 77° K	Hg _{1-x} Cd _x Te ALLOY COMPOSITIONS
10.8	0.2130
11.0	0.2120
11.2	0.2105
11.8	0.2070
12.0	0.2060
12.2	0.2045
12.8	0.2015
13.0	0.2005
13.2	0.1995

2.4 EPOXY INFRARED SPECTRAL TRANSMISSION STUDY

The infrared transmission properties of six epoxies and bonding material suitable for use in three-layer HgCdTe detector fabrication were examined experimentally in the 8-14 μm spectral range. This section presents these data and discusses the selection of the epoxy used. A list of the epoxies and bonding materials is contained in Table 2.1

Samples of six epoxies were prepared and pressed between two flat Irtran windows. The thickness of the epoxy samples was approximately 25 μm , which is on the order of the thickness which is used in detector fabrication. Transmission spectra were taken for these six samples at room temperature (300°K) between 8 μm and 14 μm . These data are shown in Figure 2.3.

On the basis of these data, Epoxy A was selected for the critical bonding layer between the top and middle detectors and between the middle and bottom detectors. It exhibited the best overall optical transmission between 11.0 μm and 13.0 μm , and, at the time, appeared to be chemically and mechanically compatible with the processing used in HgCdTe detector fabrication.

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TABLE 2.1 SAMPLE DESIGNATION, TRADE NAMES AND MANUFACTURERS OF EPOXIES
AND BONDING AGENTS USED IN THIS STUDY

SAMPLE DESIGNATION	TRADE NAME	MANUFACTURER
A	UNISET	AMICON CORPORATION
B	H54	EPOXY TECHNOLOGY, INC.
C	H81	EPOXY TECHNOLOGY, INC.
D	310	EPOXY TECHNOLOGY, INC.
E	301	EPOXY TECHNOLOGY, INC.
F	KMER	EASTMAN KODAK

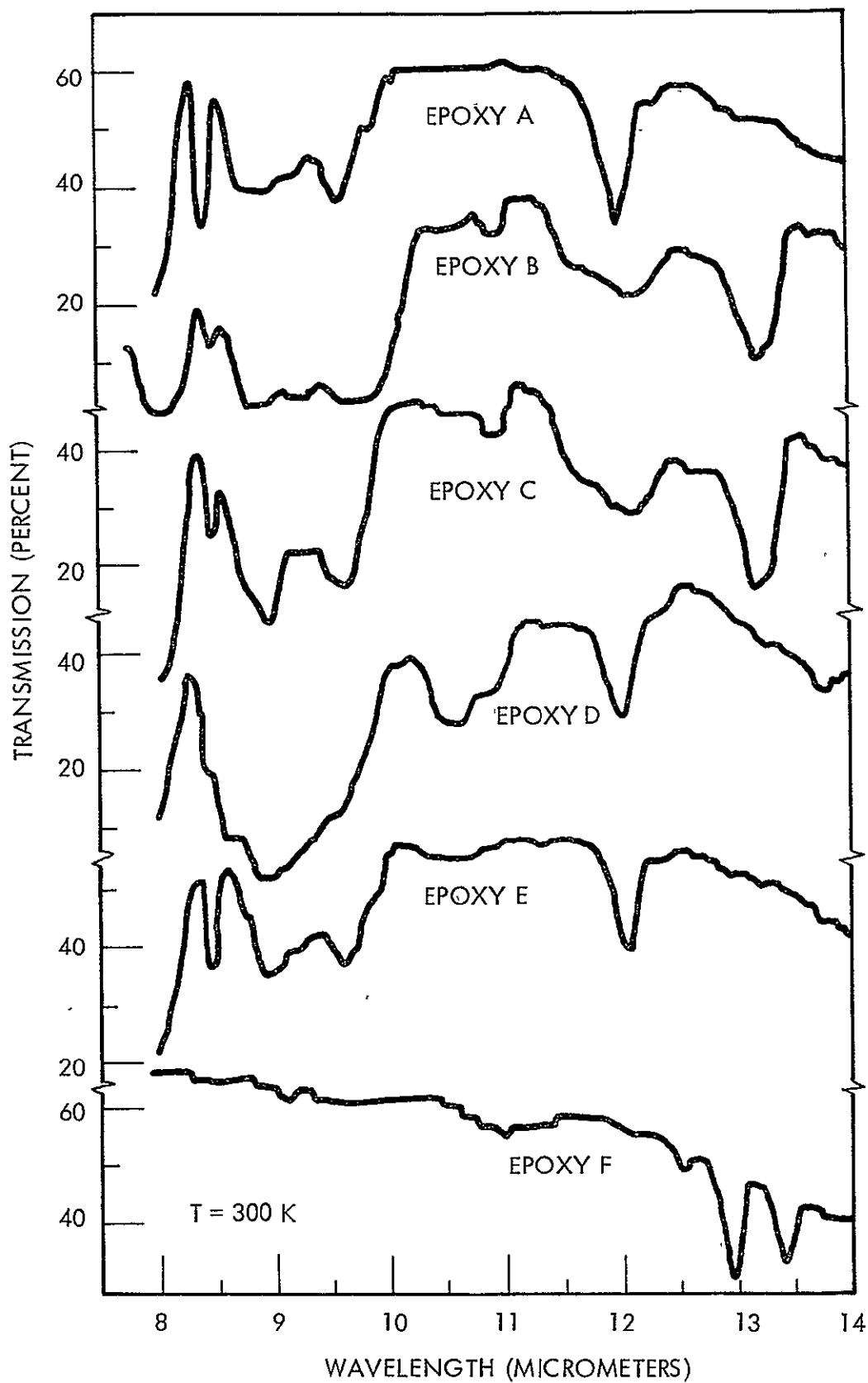


Figure 2.3 TRANSMISSION SPECTRA AT 300°K FOR SIX EPOXIES

SECTION 3

THREE-COLOR DETECTOR MODULE PERFORMANCE DATA

This section discusses the performance data for the two long-wavelength three-color HgCdTe detector modules fabricated in this program.

The detailed test reports for each of these modules are contained in Appendices B and C of this report. The performance data of each module are summarized in Table 3.1. The relative spectral response data for the two modules are shown in Figures 3.1 and 3.2.

The top element in each module had substantially higher performance than the middle and bottom elements; probably this is due to the fact that it was the last element to be fabricated and hence experienced much less processing damage than did the middle and bottom elements. The spectral response bands of the top elements, 10.4-10.8 μm for module S-1 and 10.3-11.1 μm for module S-2, are reasonably close to the design goal band of 10.1-11.0 μm .

The lower edge of the wavelength band of each top element is determined by the band pass filter cut-on edge at 10.34 μm . The transmission spectrum of the filters used over each three-color detector assembly is given in Appendix D of this report. Similarly, the long wavelength edges of the relative response spectra for both bottom elements are determined by the long-wavelength edge of the filter transmission at about 13.2 μm .

The relative response spectra of the middle and bottom elements of module S-1 (Figure 3.1) and the bottom element of module S-2 (Figure 3.2) show strong minima at about 12.2 μm . This is due to the structure in the transmission spectrum of the epoxy used (Epoxy A), as can be seen from the epoxy data shown in Figure 2.3.

Further interpretation of the relative response spectra of the middle and bottom elements, shown in Figures 3.1 and 3.2, is complicated by the relatively poor performance of these elements. In the case of module S-1, both the middle and bottom elements had virtually identical relative response spectra. Since the middle detector should have had a cutoff wavelength in the vicinity of 12 μm , this can only be explained by assuming that there was unintentional electrical shorting between the two lower elements so that they were electrically in parallel. In the case of module S-2, the middle detector has a relative spectral response virtually identical to that of the top element, which also indicates unintentional electrical shorting between these two elements.

MODULE	ELEMENT	RESISTANCE (ohms)		BIAS CURRENT (mA)	RESPONSIVITY R_λ (volts/watt)	DETECTIVITY D^* (cm-Hz ^{1/2} /watt) ^{1/2}	PEAK WAVELENGTH (micrometers)	WAVELENGTH BAND (micrometers)
		300°K	77°K					
LK193A1 S/N S-1	TOP	70	927	0.3	3,370	6.2×10^9	10.6	10.4-10.8
	MIDDLE	16	17	5.0	1.1	9.4×10^7	12.9	10.9-13.2
	BOTTOM	15	13	5.0	0.6	5.5×10^7	12.8	11.4-13.2
LK193A1 S/N S-2	TOP	48	337	1.0	3,750	2.8×10^9	10.7	10.3-11.1
	MIDDLE	36	207	1.5	870	2.8×10^9	10.8	10.4-11.1
	BOTTOM	17	16	50	51	2.0×10^9	12.7	12.3-13.1

Table 1 SUMMARY OF PERFORMANCE DATA FOR THE TWO LONG-WAVELENGTH THREE-COLOR HgCdTe MODULES DELIVERED ON THIS PROGRAM. ALL DATA ARE FOR THE OPERATING TEMPERATURE OF 77°K UNLESS OTHERWISE SPECIFIED.

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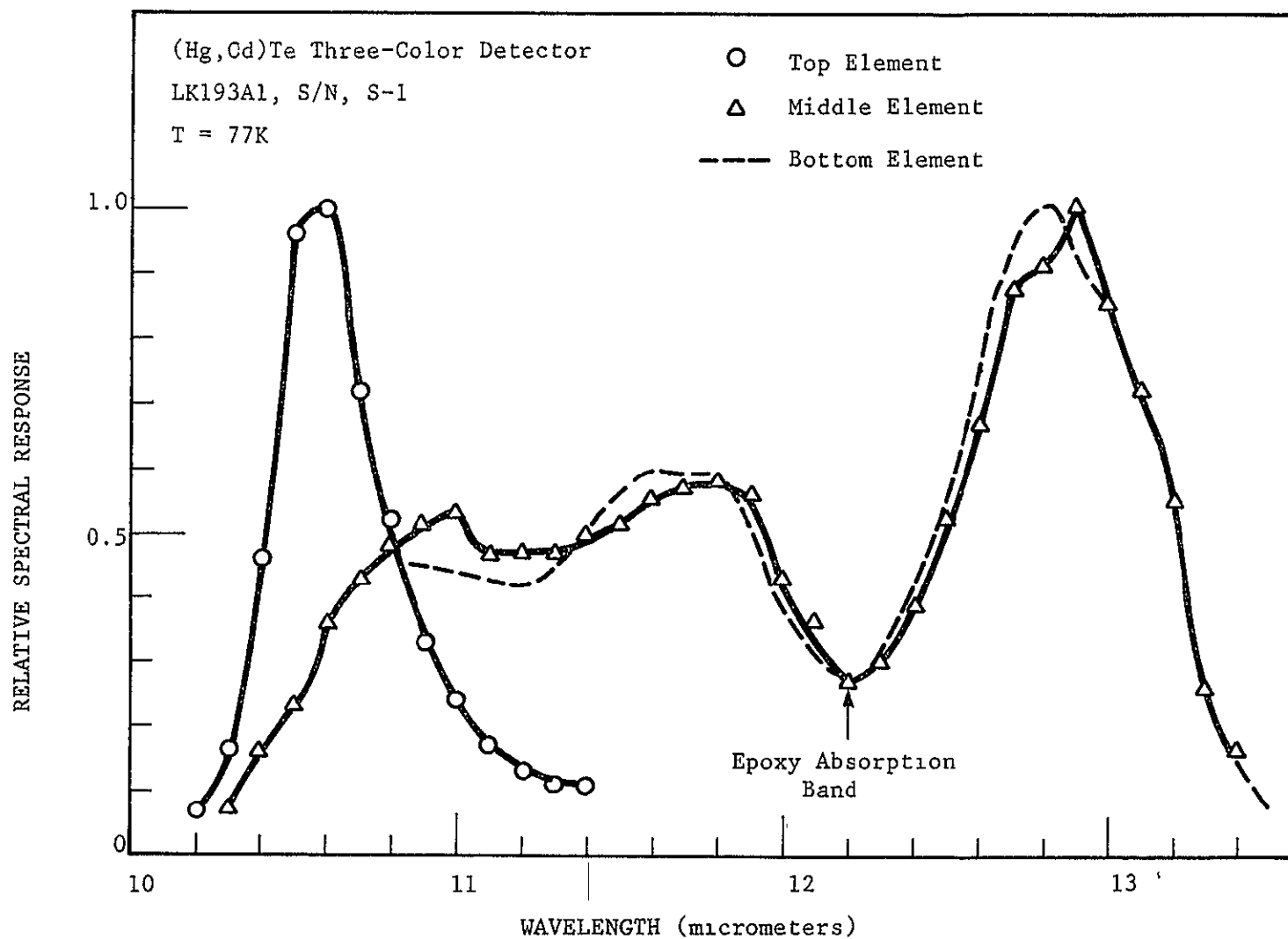


Figure 3.1 RELATIVE SPECTRAL RESPONSE DATA FOR HgCdTe THREE-COLOR MODULE
LK193A1-S/N-S-1

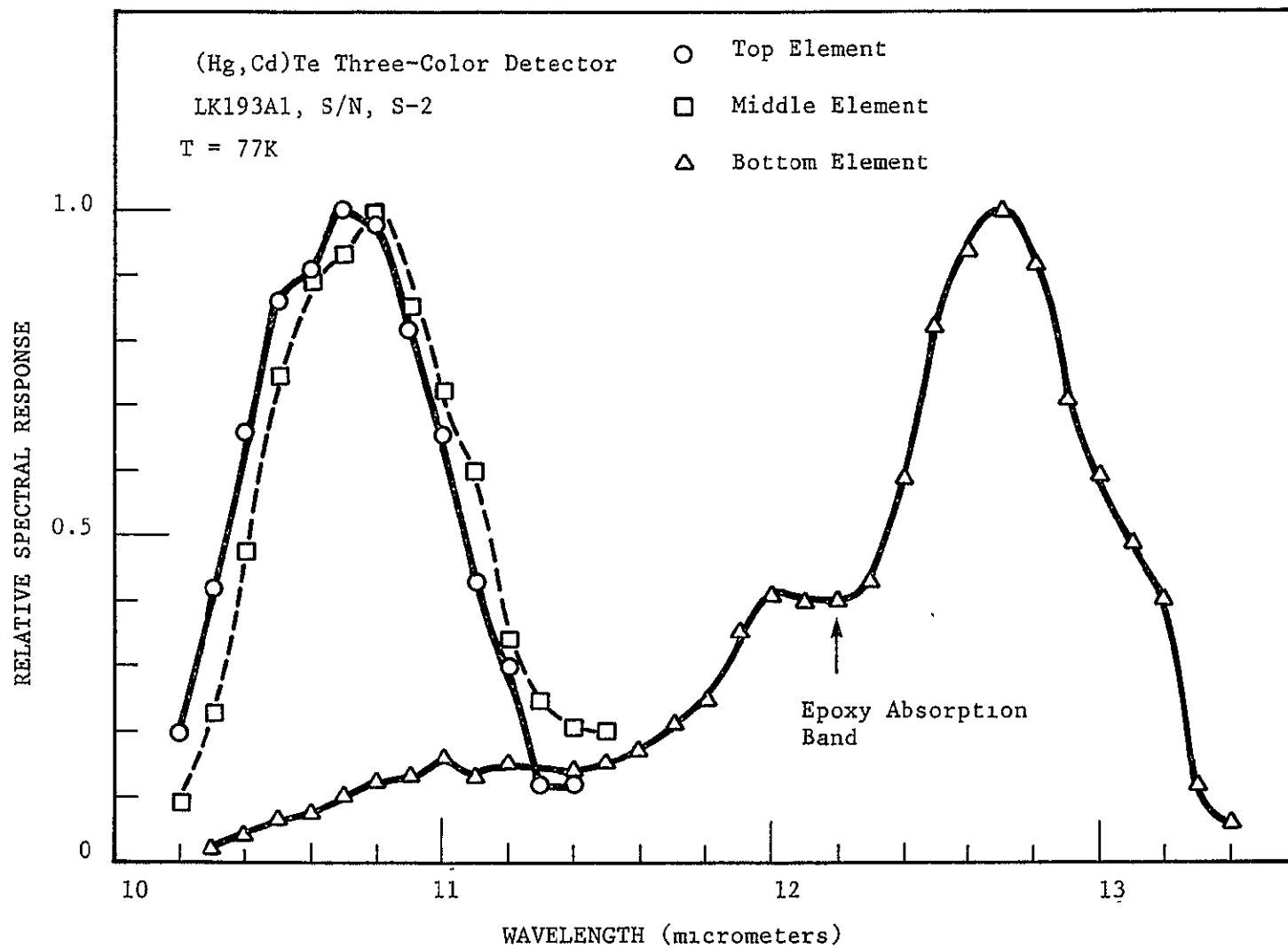


Figure 3.2 RELATIVE SPECTRAL RESPONSE DATA FOR HgCdTe THREE-COLOR DETECTOR MODULE
LK193-S/N-S-2

The problems of poor performance and anomalous spectral response in the middle and bottom detectors are all probably due to mechanical damage experienced by these elements during fabrication. Several problems were noted during the final fabrication run which might well account for this damage and these are discussed in detail in the following section.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

In summary, this program experimentally demonstrated the feasibility of multilayered three-color HgCdTe Photoconductive detectors. Phase I demonstrated that the mechanical and fabrication difficulties associated with the 1- μ m - 3- μ m, 3- μ m - 6- μ m, and 6- μ m - 11- μ m spectral bands. (Figure 1.1 and Appendix A). Phase II of this program has partially demonstrated that the multilayered three-color approach defined in Phase I can be extended to fairly narrow spectral bands in the 10 μ m-13 μ m wavelength range.

Certain difficulties were encountered during Phase II in the fabrication of these long-wavelength three-color layered detector modules:

1. Great difficulty was encountered in predicting the cutoff wavelength of the starting material. Effort should be directed to improving the non-destructive technique of predicting the performance of the starting material. Effort should also be directed to developing a technique that would enable testing of each level of detector fabrication.
2. Thermo-compression bonding to the contact pads of the second and third level detectors was extremely difficult due to the epoxy support under these detectors. This was one area where micro-fractures developed in the detectors and gave rise to excess noise. Emphasis must be placed on techniques which would eliminate bonding directly to the contact pads on the detector (e.g., beam lead technology used in silicon device industry).
3. Several epoxies were examined for transmitting properties in the wavelength region of interest and Epoxy A was selected. However, as the program progressed, it was discovered that with repeated immersions in solvents and acids this epoxy tended to swell and was a possible reason for cracking of the material. Effort should be directed to testing the other epoxies surveyed during this program.

The Honeywell Radiation Center has been investigating these problems for the past several years, and recently has developed a totally-evaporated-lead (TEL) technology which may solve some of the problems mentioned above. This technological breakthrough in processing enables detectors to be fabricated without wires being thermo-compression bonded to the HgCdTe material.

Continuing effort in the process development area at the Radiation Center has recently demonstrated that Epoxy B is much superior to Epoxy A with respect to attack by acids and solvents. This epoxy also has reasonably good transmission properties in the 8-14 μ m region of the infrared spectrum, as shown by the data of Figure 2.3. This epoxy should be used in further development of HgCdTe multilayered detector modules.

APPENDIX A

This appendix contains the test report for the first three-color HgCdTe multilayered photoconductive detector module delivered to NASA Johnson Space Center. This module covered the $1\mu\text{m}$ - $3\mu\text{m}$, $4\mu\text{m}$ - $6\mu\text{m}$, and $7\mu\text{m}$ - $11\mu\text{m}$ spectral bands.

TEST REPORT NO. 22146-2

FOR

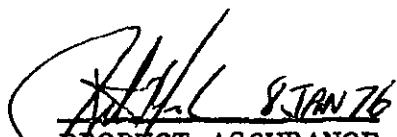
LK193A1 S/N U-1 INFRARED DETECTOR

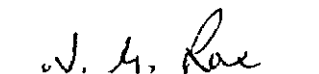
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CUSTOMER P.O. NO.

NAS9-14180


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PRODUCT ASSURANCE
ENGINEER


PROJECT ENGINEER


PROGRAM MANAGER

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2.0	DESCRIPTION OF DETECTOR
3.0	PERFORMANCE TABLE
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5.0	DETECTOR READOUT CIRCUITRY
6.0	HANDLING AND USE PRECAUTIONS

NOTE: PLEASE READ HANDLING AND PRECAUTIONS
BEFORE USING THIS DETECTOR.

1.0 INTRODUCTION

The multi-layered (Hg,Cd)Te detector is sensitive to three infrared bands. Nominal cut-off wavelengths for each band are as follows:

Channel 1 - 3 microns
Channel 2 - 6 microns
Channel 3 - 11 microns.

The multi-layered detector is mounted in a cryonique, #KD-101, dewar.

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TEST REPORT NO. 22146-2 (DEVICE) LK193A1 (SERIES) K1 (S/N) U-1CONTRACT NO. NAS9-14180CUSTOMER NASA/Johnson Space Center

2.0 DESCRIPTION OF DETECTOR

HRC Identification Number	<u>R50572S43D2</u>
Type of Detector	<u>Photoconductive (Hg,Cd)Te</u>
Date of Manufacture	<u>April, 1975</u>
Window Material	<u>Irtran II</u>

Element

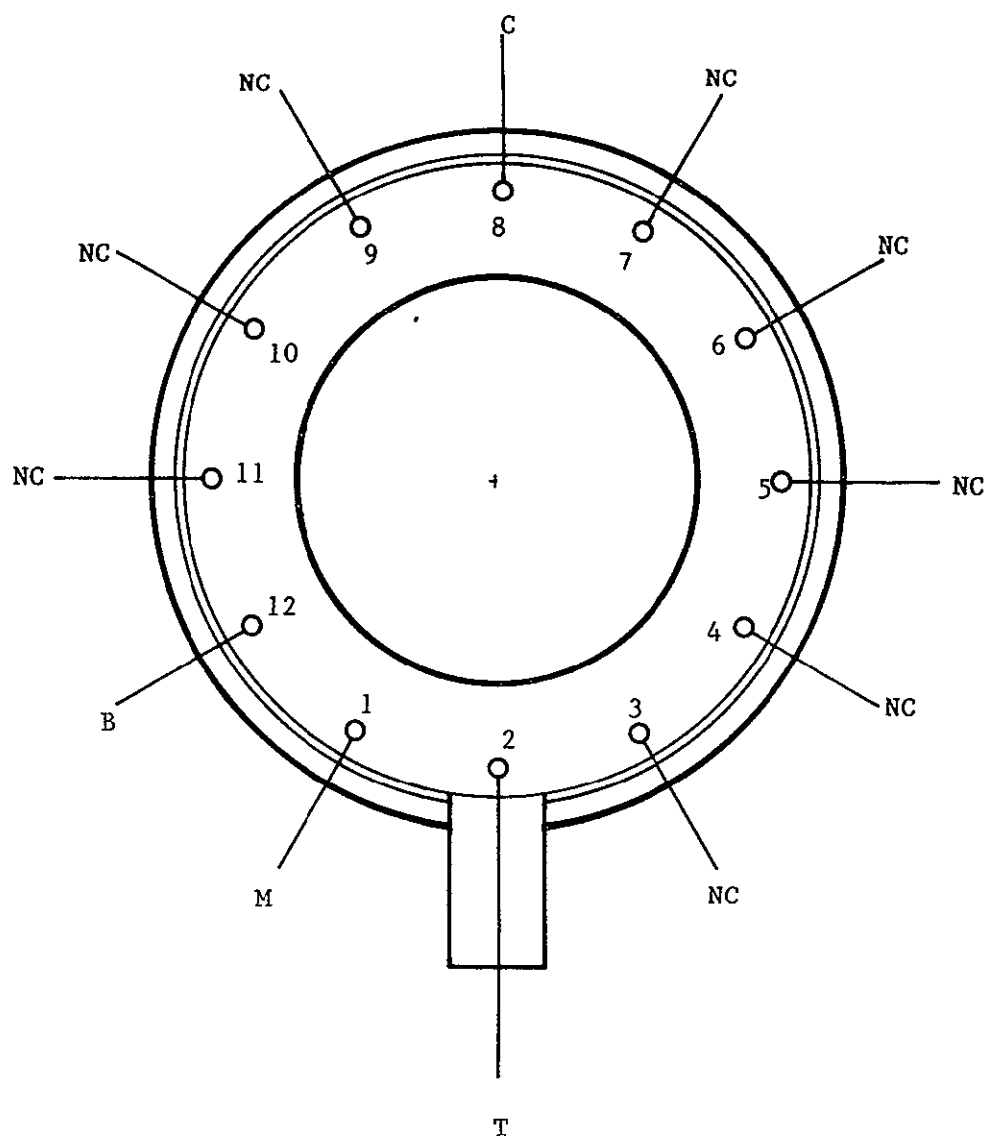
Length	<u>.49</u>	<u>MM</u>
Width	<u>.53</u>	<u>MM</u>
Area	<u>.26</u>	<u>MM²</u>
Field-of-View (Measured from the Center of Detector)	<u>49°</u>	<u>Degrees</u>

3.0 PERFORMANCE TABLE

CHANNEL	CUTOFF WAVELENGTH (MICROMETERS)	RESISTANCE (OHMS)		OPTIMUM CURRENT (mA)	DETECTIVITY $D^*_\lambda (\lambda_{\text{peak}}, f, 1\text{Hz})$ ($10^{10} \text{ cm-Hz}^{1/2}/\text{watt}$)		RESPONSIVITY R_λ (10^3 volts/watt)
		300°K	77°K		f=1kHz	f=10kHz	
1 (TOP)	2.9	2030	970	0.3	5.1	13.8	13.1
2 (MIDDLE)	6.0	76.9	45.9	10	2.3	3.9	1.59
3 (BOTTOM)	11.4	17.7	32.6	10	1.7	3.0	2.77

ALL DATA FOR T = 77° K UNLESS OTHERWISE SPECIFIED

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T = TOP DETECTOR
 M = MIDDLE DETECTOR
 B = BOTTOM DETECTOR
 C = COMMON DETECTOR LEAD (NOT CONNECTED TO DEWAR BODY)
 NC = NO CONNECTION

Figure A1. TOP VIEW OF DEWAR SHOWING PIN CONNECTIONS FOR 3-COLOR DETECTOR UNIT LK193A1-S/N-U1

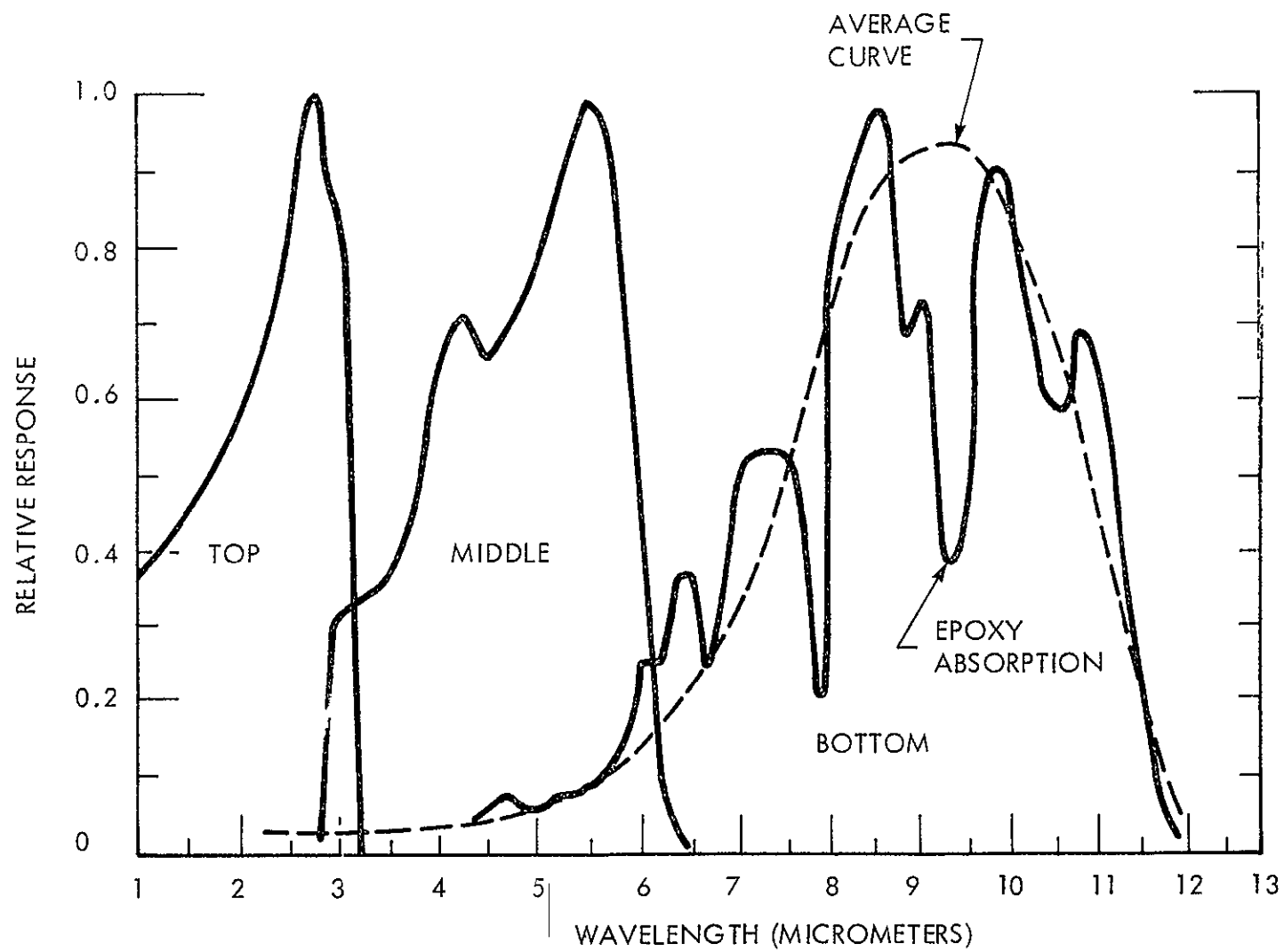


Figure A2. RELATIVE SPECTRAL RESPONSE DATA FOR THREE-COLOR HgCdTe PHOTOCONDUCTIVE MODULE LK193A1 S/N U-1. DATA ARE TAKEN AT 77° K.

4.0 CONDITIONS OF MEASUREMENT

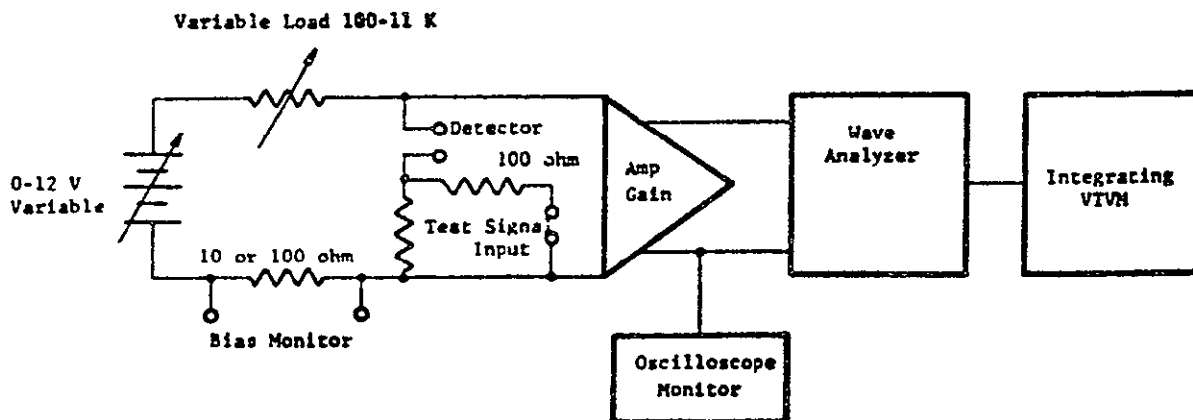
Detector Temperature	77°K
Chopping Frequency	Specified
Detector Area (A _D)	Specified
Orifice Area A _{BB}	Specified
Blackbody Temperature (T _B)	
Background Temperature (T _c)	300 °K
Emissivity	
Blackbody (ε _B)	1.0
Chopper (ε _C)	1.0
Noise Bandwidth (Δf)	Specified
Chopper RMS Factor (K ₁)	0.35
Detector to Orifice Distance (D)	Specified
Stefan-Boltzman Constant (σ)	5.67x10 ⁻¹²
RMS Noise Correction (K ₃)	1.12
Amplifier Gain (same for signal & noise)(G)	Specified
D* Formula:	

$$D^*_{bb} = \frac{(\Delta f)^{\frac{1}{2}} (A_D)^{\frac{1}{2}}}{P_1} \times \frac{S}{N} \times \frac{1}{K_3}$$

$$P_1 = \frac{K_1}{\pi D^2} \sigma (\epsilon_B T_B^4 - \epsilon_C T_C^4) A_{BB} A_D \times \tau_w$$

$$Resp_{BB} = \frac{S}{A_D G P_1}$$

5.0 DETECTOR READOUT CIRCUITRY



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6.0 HANDLING AND PRECAUTIONS FOR HRC PRECISION I.R. DETECTORS

This precision infrared detector was built in the laboratories of the Honeywell Radiation Center under the utmost care. This device was produced using some of the most modern technology in existence. However, as with any precision piece of equipment, there are tolerance limitations to which it can be subjected physically, thermally and electrically.

6.1 Operating Temperature

The device is designed to operate at the approximate temperatures noted in Section 4.0 of this report.

6.2 Storage

This unit is designed to be stored at temperatures up to 185°F (85°C) for short periods of time. Do not exceed this limit. Prolonged exposure to high temperatures may produce a degradation of device performance.

6.3 Window and Housing

Parts may crack or break if subjected to high impact. Always transport device in the container in which it was shipped.

6.4 Detector Element Burnout

The detector element is capable of dissipating only milliwatts of power. Do not overbias.

A. Caution: If lead from detector device should break contact with the test circuit:

1. Turn off bias and amplifier power source.
2. Discharge coupling capacitor by shorting test leads.
3. Reconnect detector element to bias supply.
4. Turn bias power on again.

B. When the detector is connected to any power source, there must be no voltage differential between the contacts until after circuit is complete.

C. Do not use any amplifier circuitry that will produce current into detector or generate current surges.

D. The detector should be operated only in the cooled condition. If it is possible that the cooling unit may malfunction without operator's knowledge, the manufacturer suggests that a current/voltage limiter be installed in the bias circuit to prevent a runaway condition when the detector element warms.

6.5 Protection from Meter Voltage

Normally, the meters used to measure resistance utilize a 1.5 volt battery. The current generated by the battery is sufficient to cause detector burnout. Therefore, if it is necessary to measure resistance, observe the following:

- A. Use a Wheatstone bridge with an external battery to produce a current/voltage level compatible with the manufacturer's test results.
- B. When the device is in an operating circuit or system, use a VTVM with selector switch set to voltage. Read voltage drop across detector and compute resistance by Ohm's Law. Be cautious of power ground loops between VTVM and detector circuitry. Connect common ground first; then connect VTVM to high side of detector. If VTVM is of a high impedance, it is advisable to use a series limiting resistance in VTVM lead. Resistance values up to 1% of VTVM input impedance will cause no voltage reading errors.

6.6 Moisture

Before cooling, remove all traces of moisture in the dewar well. This will minimize thermal transfer problems and prevent dewar well breakage caused by the expansion of water when it freezes.

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APPENDIX B

Test Report for Long Wavelength Three-Color HgCdTe Detector
Module LK193A1 - S1.

TEST REPORT NO. 24215-1

FOR

LK193A1 SERIAL NUMBER S-1

Honeywell Inc.
Radiation Center
2 Forbes Road
Lexington, Massachusetts 02173

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TABLE OF CONTENTS

Section	Title
1.0	HANDLING PRECAUTIONS
2.0	CONDITIONS OF MEASUREMENT
3.0	DETECTOR READOUT CIRCUITRY
4.0	DESCRIPTION OF DETECTOR
5.0	PERFORMANCE DATA SUMMARY
6.0	SPECTRAL GRAPHS

*PLEASE READ "HANDLING AND PRECAUTIONS"
BEFORE USING THIS DETECTOR.

1.0 HANDLING PRECAUTIONS

This precision infrared detector was built in the laboratories of the Honeywell Radiation Center under the utmost care. This device was produced using some of the most modern technology in existence. However, as with any precision piece of equipment, there are tolerance limitations to which it can be subjected physically, thermally, and electrically.

1.1 Operating Temperature

The device is designed to operate at the approximate temperatures noted in Section 2.0 of this report.

1.2 Storage

This unit is designed to be stored at temperatures up to 185°F (85°C) for short periods of time. Do not exceed this limit. Prolonged exposure to high temperatures may produce a degradation of device performance.

1.3 Window and Housing

Parts may crack or break if subjected to high impact. Always transport device in the container in which it was shipped.

1.4 Detector Element Burnout

The detector element is capable of dissipating only milliwatts of power. Do not overbias.

- A. Caution: If lead from detector device should break contact with the test circuit:
 - 1. Turn off bias and amplifier power source.
 - 2. Discharge coupling capacitor by shorting test leads.
 - 3. Reconnect detector element to bias supply.
 - 4. Turn bias power on again.
- B. When the detector is connected to any power source, there must be no voltage differential between the contacts until after circuit is complete.
- C. Do not use any amplifier circuitry that will produce current into detector or generate current surges.
- D. The detector should be operated only in the cooled condition. If it is possible that the cooling unit may malfunction without operator's knowledge, the manufacturer suggests that a current/voltage limiter be installed in the bias circuit to prevent a runaway condition when the detector element warms.

1.5 Protection from Meter Voltage

Normally, the meters used to measure resistance utilize a 1.5 volt battery. The current generated by the battery is sufficient to cause detector burnout. Therefore, if it is necessary to measure resistance, observe the following:

- A. Use a Wheatstone bridge with an external battery to produce a current/voltage level compatible with the manufacturer's test results.
- B. When the device is in an operating circuit or system, use a VTVM with selector switch set to voltage. Read voltage drop across detector and compute resistance by Ohm's Law. Be cautious of power ground loops between VTVM and detector circuitry. Connect common ground first; then connect VTVM to high side of detector. If VTVM is of a high impedance, it is advisable to use a series limiting resistance in VTVM lead. Resistance values up to 1% of VTVM input impedance will cause no voltage reading errors.

1.6 Moisture

Before cooling, remove all traces of moisture in the dewar well. This will minimize thermal transfer problems and prevent dewar well breakage caused by the expansion of water when it freezes.

1.7 Headers

Do not bend, cut or apply excessive heat to the header terminals. Cracks in the glass seal will result in loss of dewar vacuum.

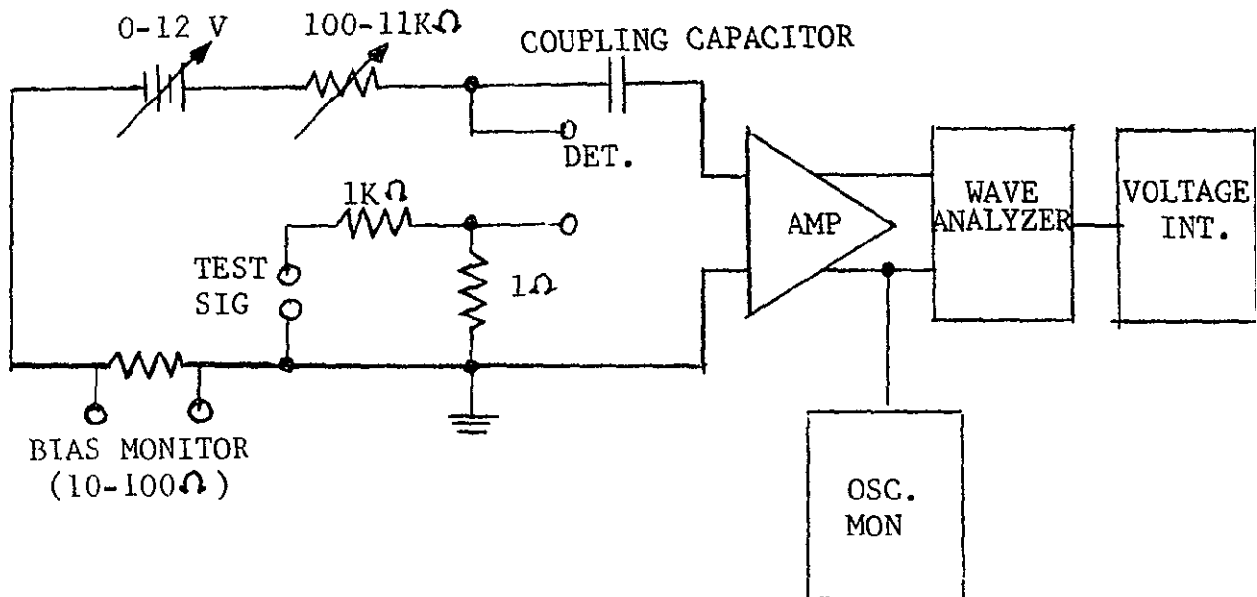
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2.0 CONDITIONS OF MEASUREMENT

Detector Temperature	77° K
Chopping Frequency	1,000 Hz
Detector Area (A_D)	See Page
Orifice Diameter (d_B)	.0847 inch
Blackbody Temperature (T_B)	500° K
Background Temperature (T_C)	300° K
Emissivity	
Blackbody (ϵ_B)	1.0
Chopper (ϵ_C)	1.0
Noise Bandwidth (f)	6 Hz
Chopper RMS Factor (K_1)	0.35
Detector to Orifice Distance (D)	25.4 cm
Stefan-Boltzmann Constant (K_2)	5.67×10^{-12} watt $\text{cm}^{-2}(\text{°})$
RMS Noise Correction (K_3)	1.12
Amplifier Gain (same for signal & noise)	~ 4200
D* Formula:	

$$D^*_{BB} = \frac{4D^2 (\Delta f)^{1/2}}{K_1 K_2 K_3 d_B^2 \sqrt{A_D} (\epsilon_B T_B^4 - \epsilon_C T_C^4)} \times \frac{S}{N}$$

3.0 DETECTOR READOUT CIRCUITRY



4.0 DESCRIPTION OF DETECTOR

HRC Identification	40772 S81 50572 S162 60873 S136
Type of Detector	Photoconductive
Window Material	IRTRAN II

ELEMENT

	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Units</u>
Length	.513	.508	.503	mm
Width	.513	.508	.503	mm
Area	.263	.258	.253	mm

Distance to Window	6.55	mm
Field of View	40	Degrees

DEWAR

Liquid Nitrogen Hold Time	>6	Hours
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LK193A1
S/N S-1

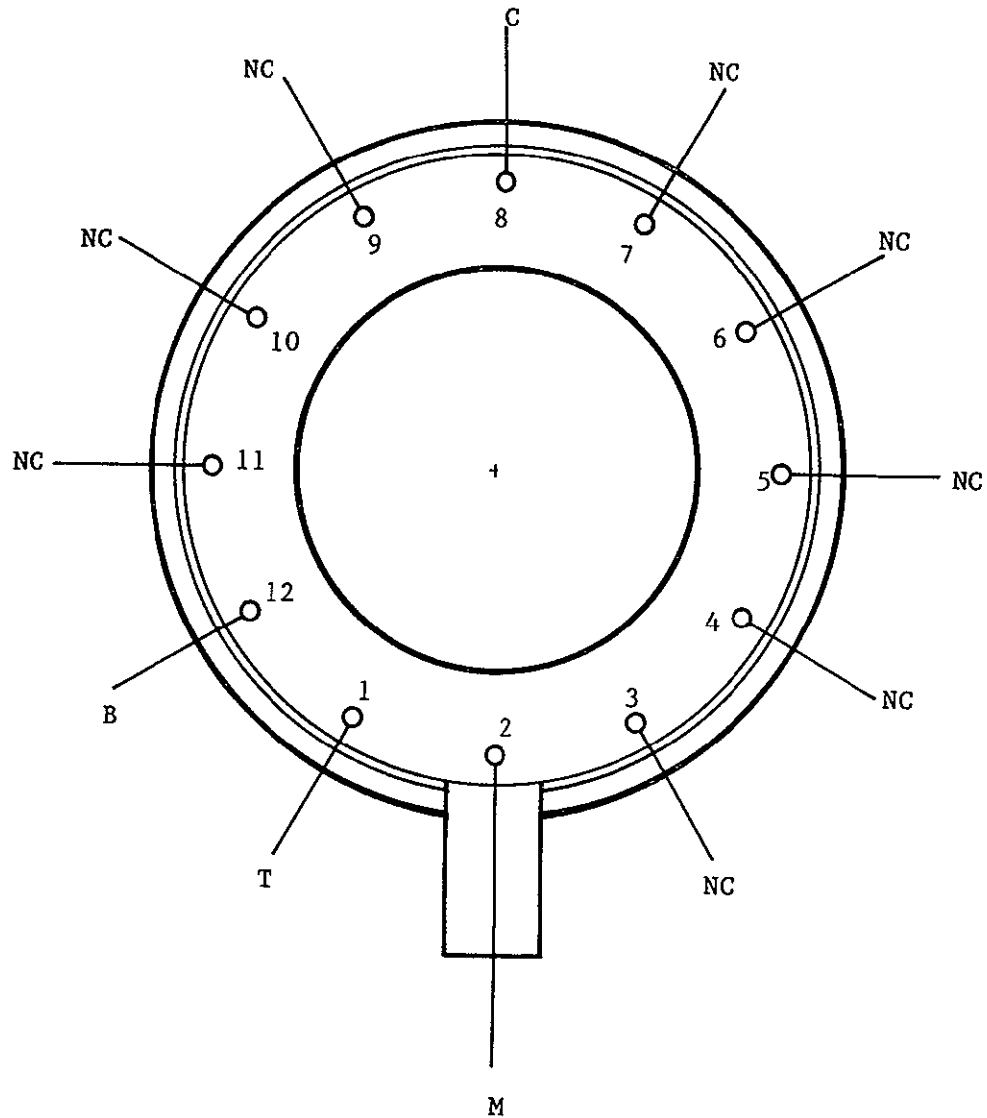
TEST REPORT NO. 24215-1
PAGE 7 OF 9

5.0 PERFORMANCE DATA SUMMARY

Element	Resistance RM Oper. Ohms	Voltage (mV)	Bias (mA)	D_{bb}^* (cmHz ^{1/2} W ⁻¹)	D_{λ} (cmHz ^{1/2} W ⁻¹)	R_{bb} (Volts/Watts)	R_{λ} (Volts/Watts)	Spectral Peak (microns)
Top	69.5 927	278	0.3	1.7E8	6.23E9	91	3.37E3	10.6
Middle	16.4 16.9	84.5	5.0	6.32E6	9.44E7	.071	1.059	12.9
Bottom	14.6 13.3	66.4	5.0	3.69E6	5.46E7	.042	.615	12.8

B8

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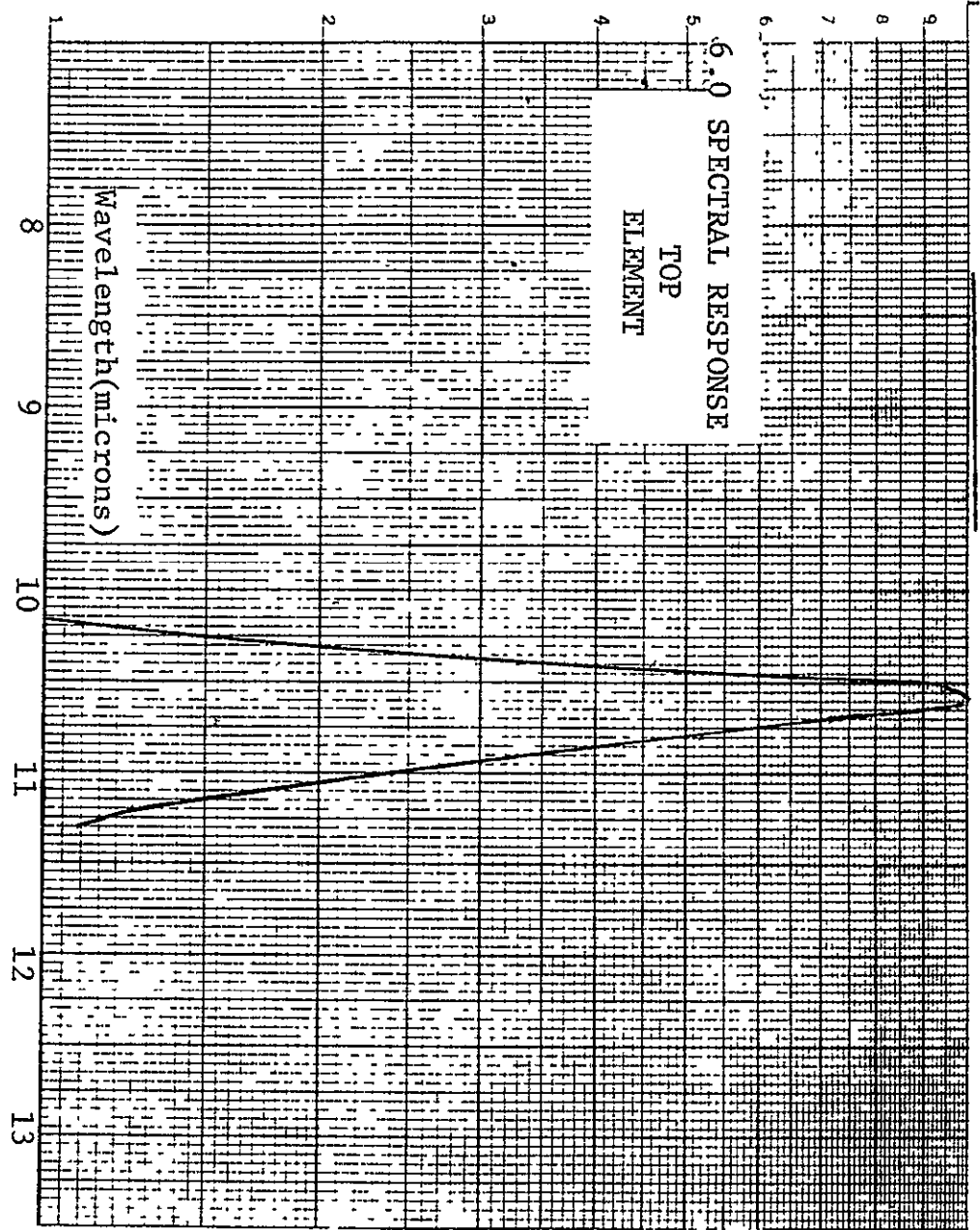


T = TOP DETECTOR
 M = MIDDLE DETECTOR
 B = BOTTOM DETECTOR
 C = COMMON DETECTOR LEAD (NOT CONNECTED TO DEWAR BODY)
 NC = NO CONNECTION

Figure B1. TOP VIEW OF DEWAR SHOWING PIN CONNECTIONS FOR 3-COLOR DETECTOR UNIT LK193A1-S/N-S1

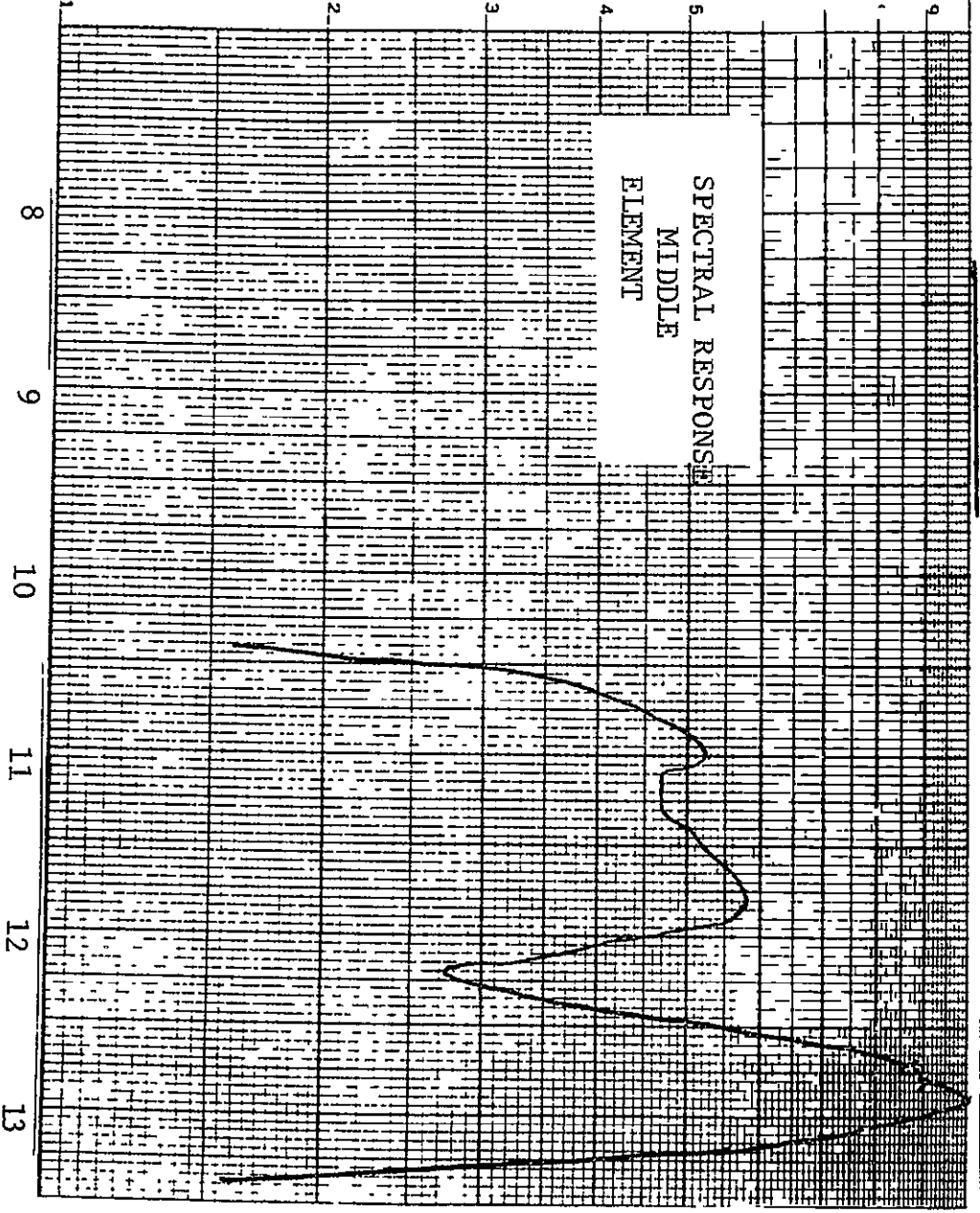
TOP

RELATIVE RESPONSE (%)



MIDDLE

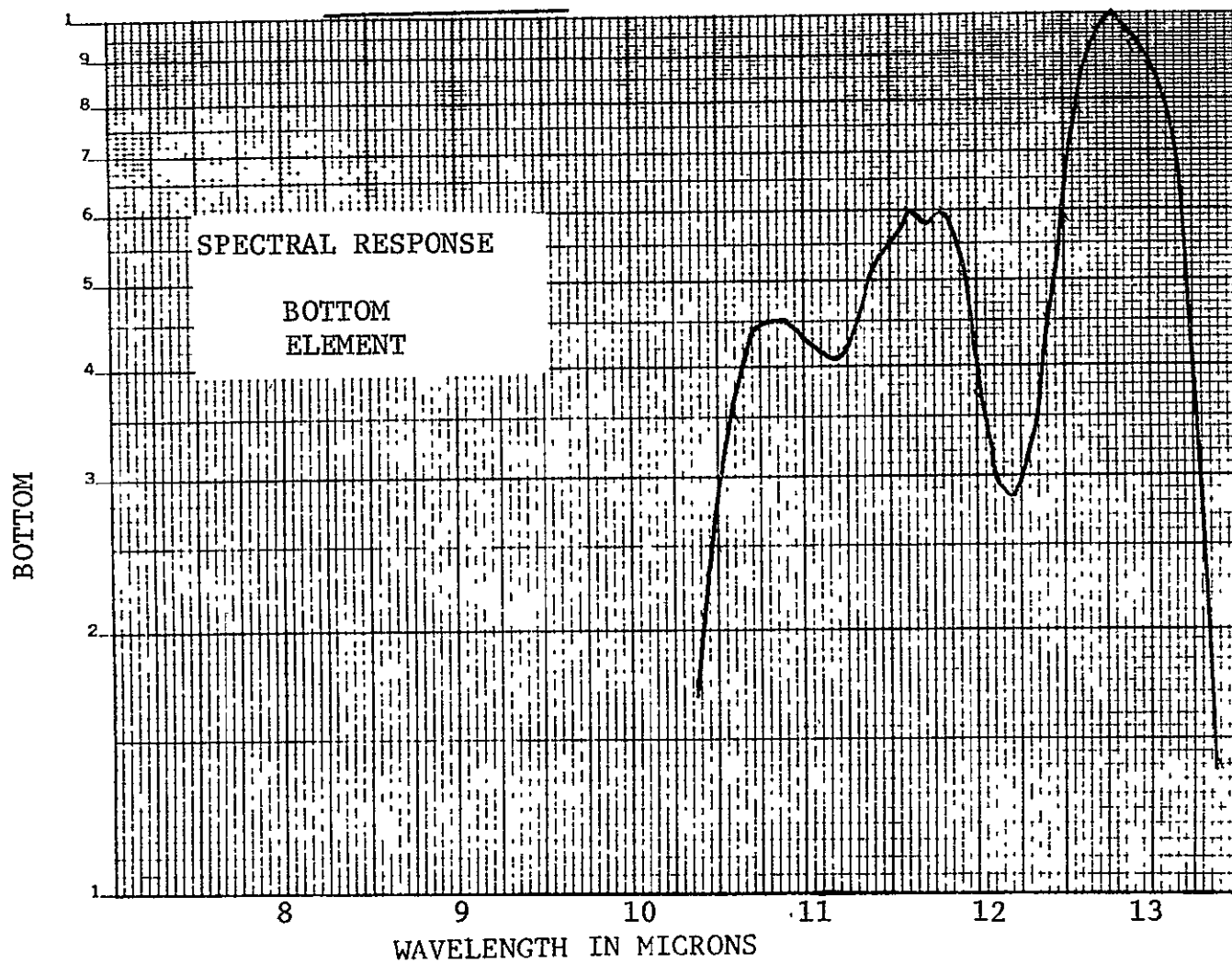
RELATIVE RESPONSE (%)



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APPENDIX C

Test Report for Long Wavelength Three-Color HgCdTe Detector
Module LK193A1 - S2.

TEST REPORT NO. 24215-2

FOR

LK193A1 SERIAL NUMBER S-2

Honeywell Inc.
Radiation Center
2 Forbes Road
Lexington, Massachusetts 02173

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TABLE OF CONTENTS

Section	Title
1.0	HANDLING PRECAUTIONS
2.0	CONDITIONS OF MEASUREMENT
3.0	DETECTOR READOUT CIRCUITRY
4.0	DESCRIPTION OF DETECTOR
5.0	PERFORMANCE DATA SUMMARY
6.0	SPECTRAL GRAPHS

*PLEASE READ "HANDLING AND PRECAUTIONS"
BEFORE USING THIS DETECTOR.

1.0 HANDLING PRECAUTIONS

This precision infrared detector was built in the laboratories of the Honeywell Radiation Center under the utmost care. This device was produced using some of the most modern technology in existence. However, as with any precision piece of equipment, there are tolerance limitations to which it can be subjected physically, thermally, and electrically.

1.1 Operating Temperature

The device is designed to operate at the approximate temperatures noted in Section 2.0 of this report.

1.2 Storage

This unit is designed to be stored at temperatures up to 185°F (85°C) for short periods of time. Do not exceed this limit. Prolonged exposure to high temperatures may produce a degradation of device performance.

1.3 Window and Housing

Parts may crack or break if subjected to high impact. Always transport device in the container in which it was shipped.

1.4 Detector Element Burnout

The detector element is capable of dissipating only milliwatts of power. Do not overbias.

- A. Caution: If lead from detector device should break contact with the test circuit:
 - 1. Turn off bias and amplifier power source.
 - 2. Discharge coupling capacitor by shorting test leads.
 - 3. Reconnect detector element to bias supply.
 - 4. Turn bias power on again.
- B. When the detector is connected to any power source, there must be no voltage differential between the contacts until after circuit is complete.
- C. Do not use any amplifier circuitry that will produce current into detector or generate current surges.
- D. The detector should be operated only in the cooled condition. If it is possible that the cooling unit may malfunction without operator's knowledge, the manufacturer suggests that a current/voltage limiter be installed in the bias circuit to prevent a runaway condition when the detector element warms.

1.5 Protection from Meter Voltage

Normally, the meters used to measure resistance utilize a 1.5 volt battery. The current generated by the battery is sufficient to cause detector burnout. Therefore, if it is necessary to measure resistance, observe the following:

- A. Use a Wheatstone bridge with an external battery to produce a current/voltage level compatible with the manufacturer's test results.
- B. When the device is in an operating circuit or system, use a VTVM with selector switch set to voltage. Read voltage drop across detector and compute resistance by Ohm's Law. Be cautious of power ground loops between VTVM and detector circuitry. Connect common ground first; then connect VTVM to high side of detector. If VTVM is of a high impedance, it is advisable to use a series limiting resistance in VTVM lead. Resistance values up to 1% of VTVM input impedance will cause no voltage reading errors.

1.6 Moisture

Before cooling, remove all traces of moisture in the dewar well. This will minimize thermal transfer problems and prevent dewar well breakage caused by the expansion of water when it freezes.

1.7 Headers

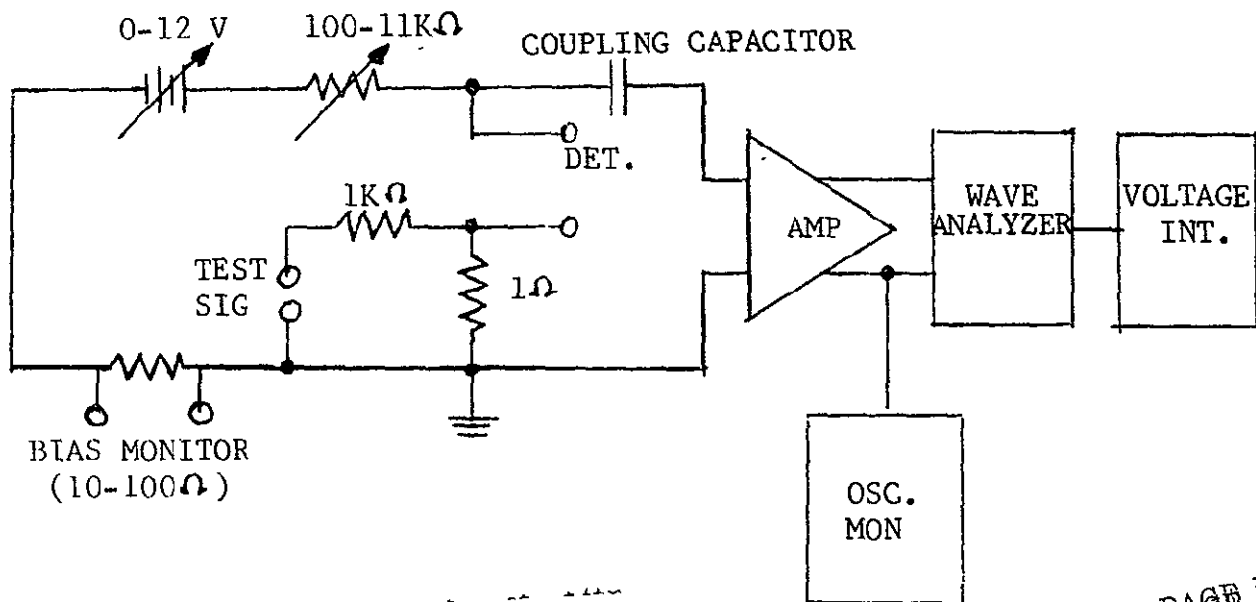
Do not bend, cut or apply excessive heat to the header terminals. Cracks in the glass seal will result in loss of dewar vacuum.

2.0 CONDITIONS OF MEASUREMENT

Detector Temperature	77° K
Chopping Frequency	1,000 Hz
Detector Area (A_D)	See Page
Orifice Diameter (d_B)	.0847 inch
Blackbody Temperature (T_B)	500° K
Background Temperature (T_C)	300° K
Emissivity	
Blackbody (ϵ_B)	1.0
Chopper (ϵ_C)	1.0
Noise Bandwidth (Δf)	6 Hz
Chopper RMS Factor (K_1)	0.35
Detector to Orifice Distance (D)	25.4 cm
Stefan-Boltzmann Constant (K_2)	5.67×10^{-12} watt $\text{cm}^{-2}(\text{°K})^{-4}$
RMS Noise Correction (K_3)	1.12
Amplifier Gain (same for signal & noise)	~ 4100
D* Formula:	

$$D^*_{BB} = \frac{4D^2 (\Delta f)^{1/2}}{K_1 K_2 K_3 d_B^2 \sqrt{A_D} (\epsilon_B T_B^4 - \epsilon_C T_C^4)} \times \frac{S}{N}$$

3.0 DETECTOR READOUT CIRCUITRY



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4.0 DESCRIPTION OF DETECTOR

HRC Identification Number	40772 S81 50572 S162 60873 S136
Type of Detector	Photoconductive
Date of Manufacture	May 1977
Window Material	IRTRAN II

ELEMENT

	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>	<u>Units</u>
Length	.513	.508	.503	mm
Width	.513	.508	.503	mm
Area	.263	.258	.253	mm
Distance to Window			7.11	mm
Field of View			40	Degrees

DEWAR

Liquid Nitrogen Hold Time	>6	Hours
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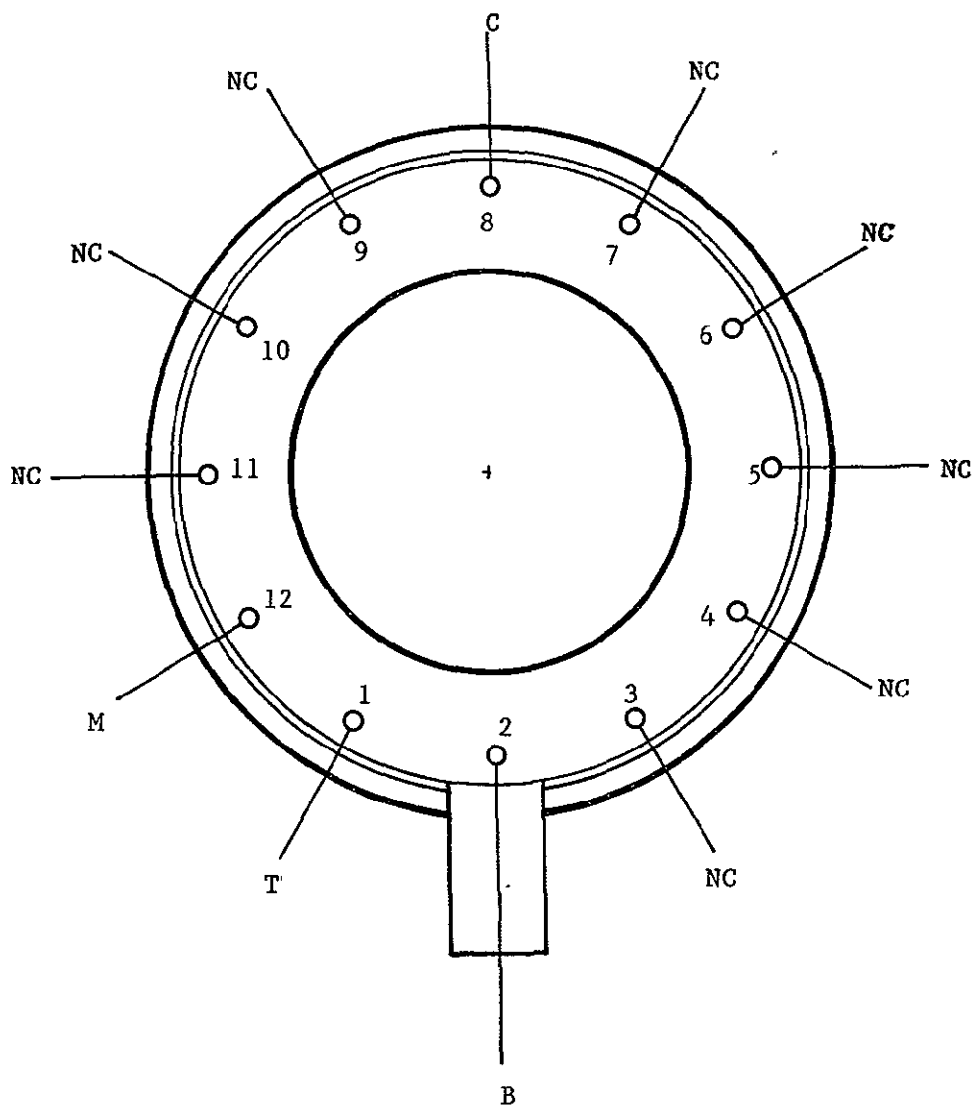
S/N S-2

TEST REPORT NO. 24215-2

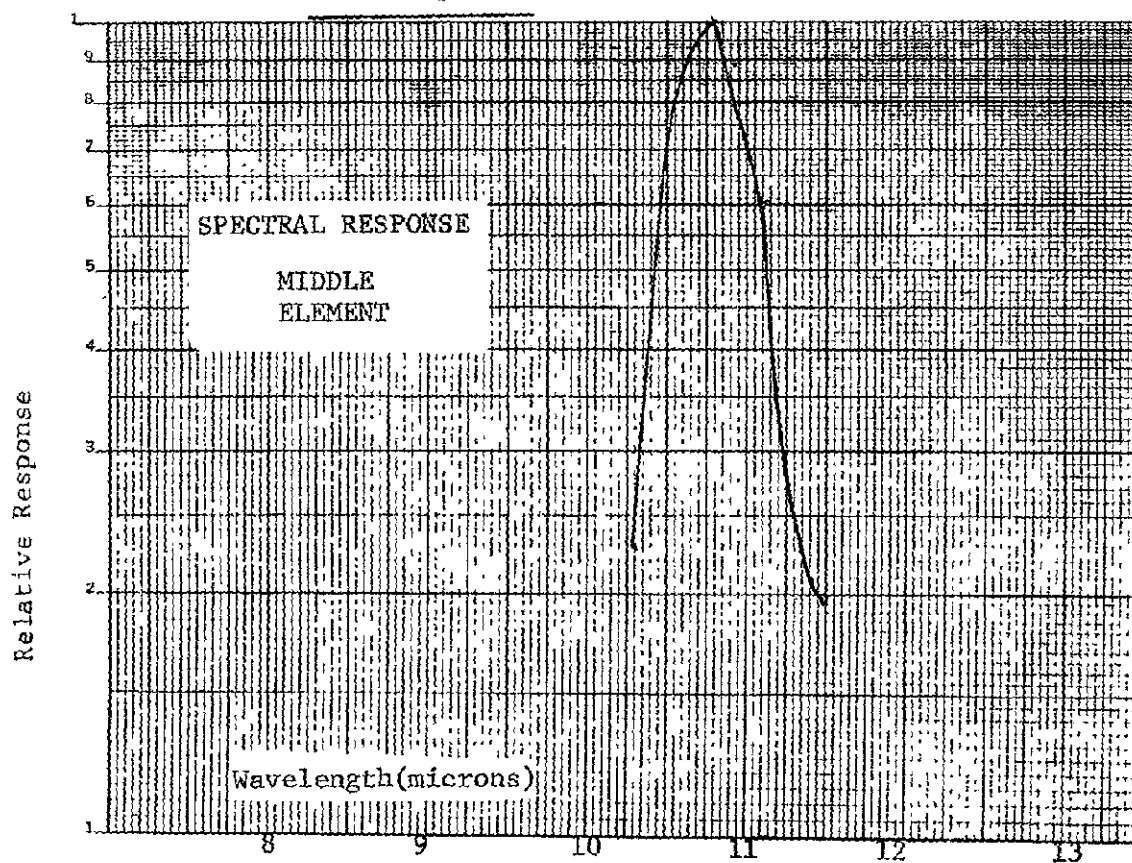
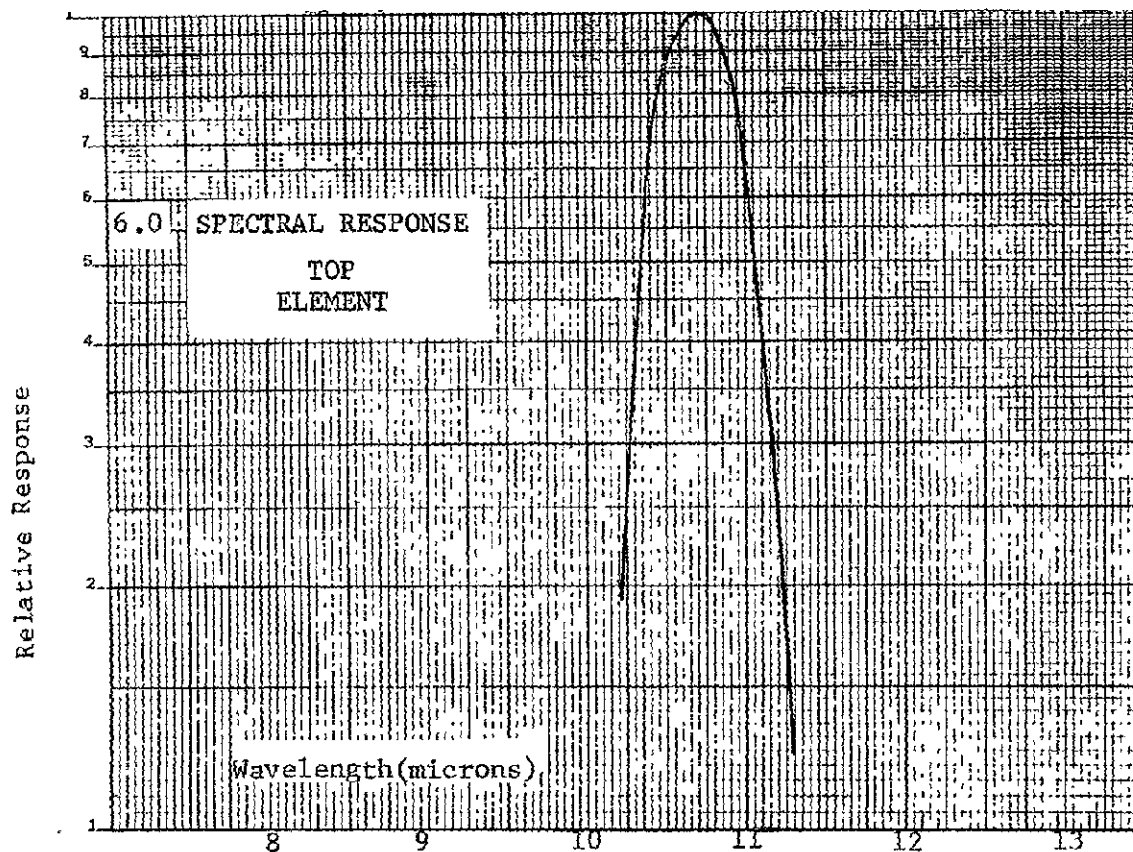
PAGE 7 OF 9

5.0 PERFORMANCE DATA SUMMARY

Element	Resistance RM Oper. Ohms		Voltage (mV)	Bias (mA)	D_{bb}^* (cmHz ^{1/2} W ⁻¹)	D_{λ} (cmHz ^{1/2} W ⁻¹)	R_{bb} (Volts/Watts)	R_{λ} (Volts/Watts)	Spectral Peak (microns)
Top	47.9	337	337	1.0	1.1E8	2.78E9	1.50E2	3.75E3	10.7
Middle	36.2	207	310	1.5	1.19E8	2.84E9	3.61E1	8.74E2	10.8
Bottom	16.9	16.4	820	50	8.53E7	2.01E9	2.18	5.14E1	12.7

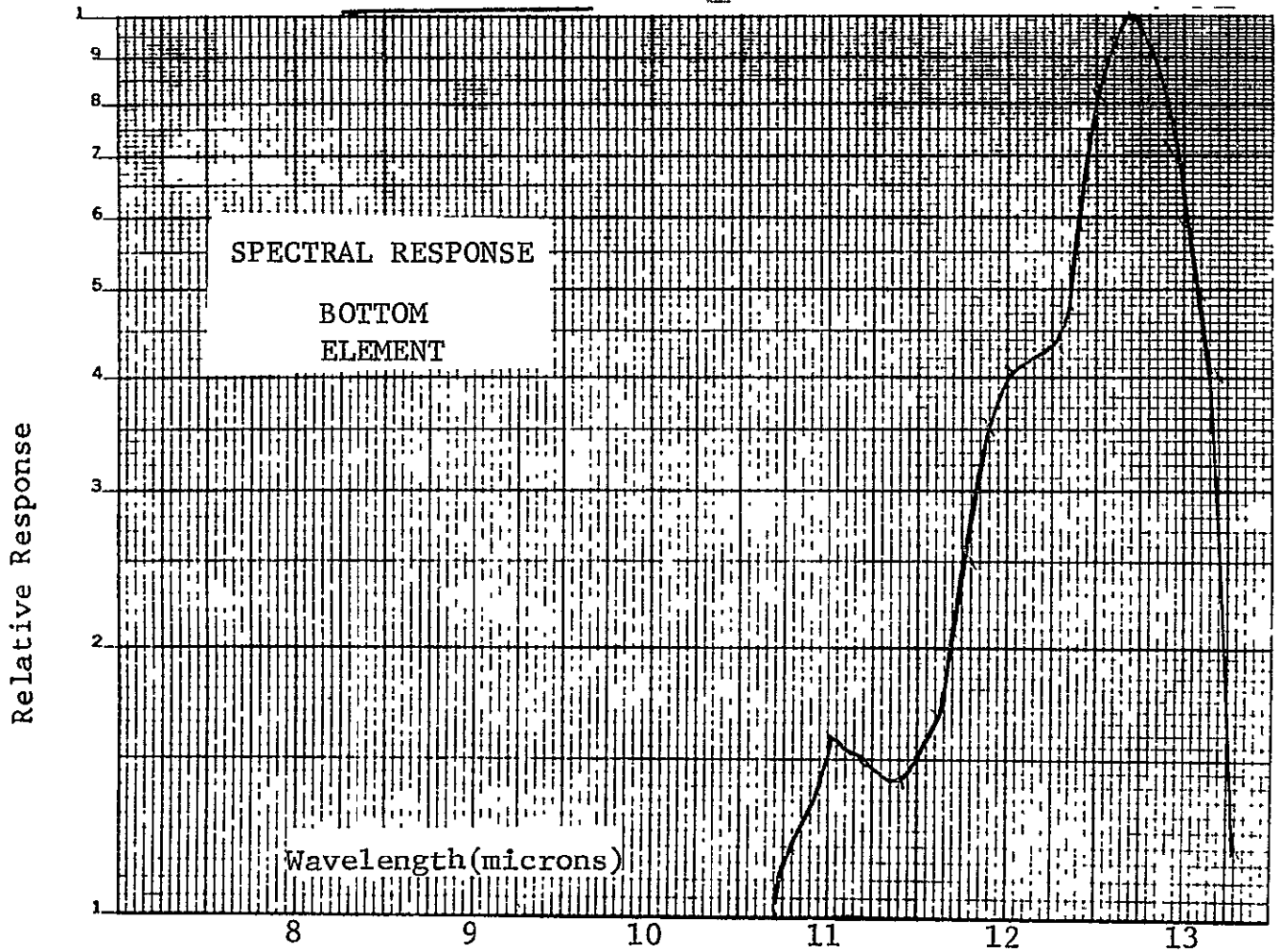


T = TOP DETECTOR
 M = MIDDLE DETECTOR
 B = BOTTOM DETECTOR
 C = COMMON DETECTOR LEAD (NOT CONNECTED TO DEWAR BODY)
 NC = NO CONNECTION



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APPENDIX D

Filter Spectral Transmission Characteristics

The spectral transmission characteristics of the optical bandpass filters mounted directly over the long wavelength three-color detectors are shown in Figure D1. The cut-onwavelength is 10.3 μm and the cutoff wavelength is 13.1 μm , and the average transmission is about 75% in this pass-band. The filter diameter is 0.3" and the thickness is 0.032".

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OCI | OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O

Run No 9024-1114-176/178
Serial No W11740-5

SAMPLE IDENTIFICATION

Filter Type WIDE BANDPASS
Material GERMANIUM
Configuration 0.3" X 0.032"

INST OPERATING PARAMETERS

☐ CARY 90 ☒ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution 2 X STD SLIT
Scan Speed 20 CM/MIN
Response INF.
Aperture 0.2"
Exposure 0 TO 100

☒ Percent Transmission
☐ Percent Reflection
☐

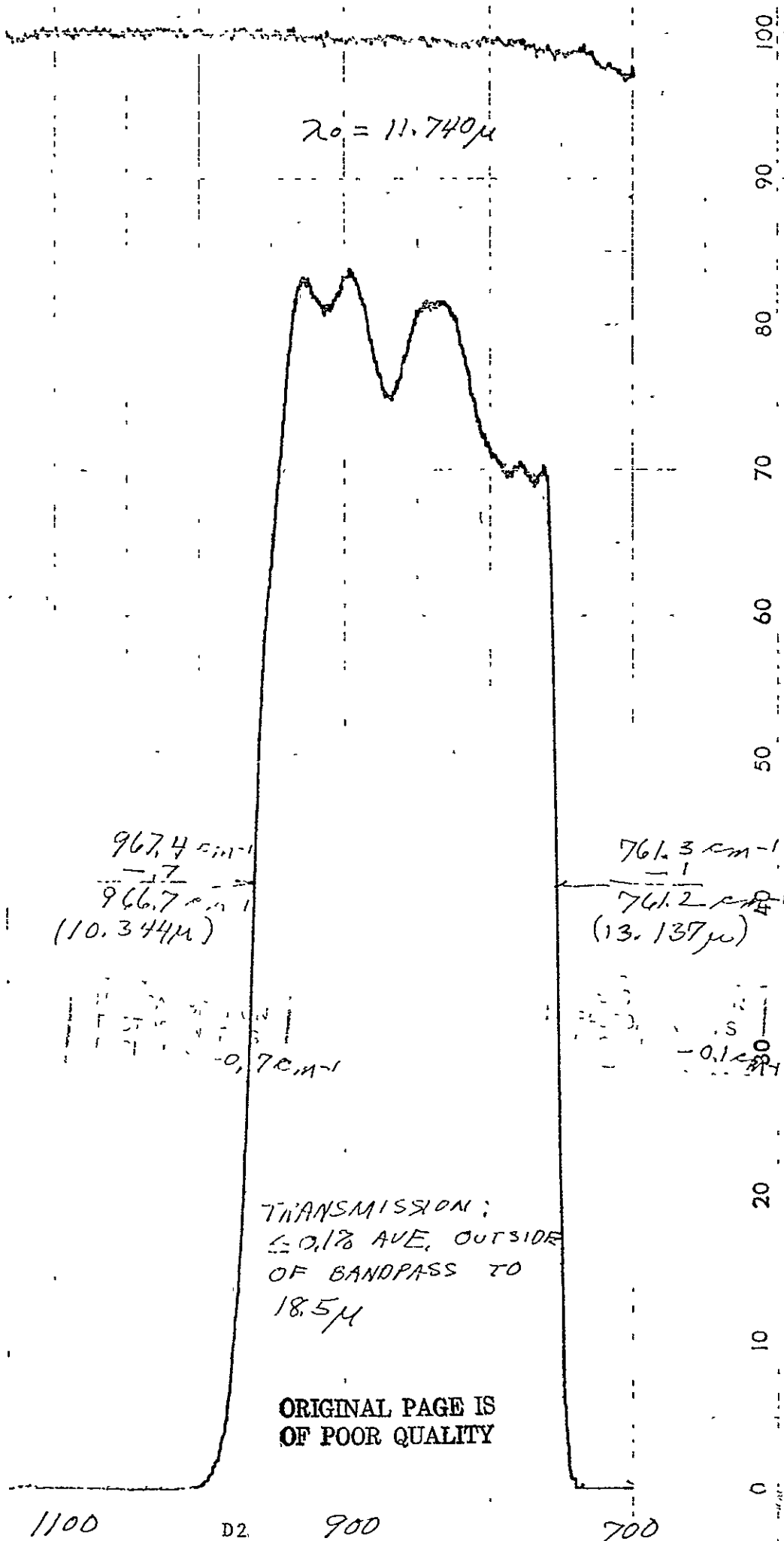
TEST CONDITIONS

Temp $\pm 25^{\circ}\text{C}$ Angle 0°

Analyst *CH* Date 2-4-76

PAGE 1 of

☒ Wavenumber
☐ Wavelength in



APPENDIX E

THREE-CHANNEL PREAMPLIFIER CHARACTERISTICS

This appendix contains design information on the three-channel low-noise preamplifier assembly. This unit was modified during Phase II of this program, and this appendix includes these modifications.

NOTE: No electronic Anti - Zap circuits are operative in this unit. Detectors should be connected or disconnected with all power off, and with detector short switch activated.

NOTES ON MULTI-DETECTOR OPERATION:

Within a Multi-Color array, each detector will require a specific optimum bias current. When operating one detector at a time, this will not generally be a problem, though in some cases required bias currents will be in excess of those available from the preamplifier module as supplied. In such a case, it will be necessary to lower the value of internal bias current limiting resistor, (connected between bias input and signal input terminals).

When operation of two or three detectors at a time is contemplated, there is a need to first optimize bias for each detector, in a manner which will allow those optimum bias currents to be reached simultaneously with the bias control pot. This can be accomplished by a sequence of steps, as follows:

(1) Each of the detectors to be run is connected individually to the channel with which it is to operate, and the bias pot adjusted to provide optimum bias. At this time, the pot settings and voltage corresponding to optimum bias should be recorded.

(2) In the cases of the two detectors requiring the lower pot settings, the bias lead must be removed from the amplifier module, and a series resistor inserted to permit optimum bias with the previously recorded highest bias pot setting.

CAUTION: In all of these steps, remember that application of excess bias voltage to a detector will destroy that detector very quickly. Always operate with one detector at a time, until step 3 below, and always lower the bias pot to zero, and operate the detector grounding switch when connecting or disconnecting a detector.

(3) Only after bias levels for three detectors have been aligned, as above, connect all three detectors with the usual detector ground and pot set to zero. Then raise bias to optimum level in small steps, especially near the end of the pot motion, checking voltage against prerecorded optimum bias voltage at each step. If any one detector indicates more than 5% over recorded bias voltage before all detectors are at optimum, steps 1 and 2 above should be repeated before proceeding.

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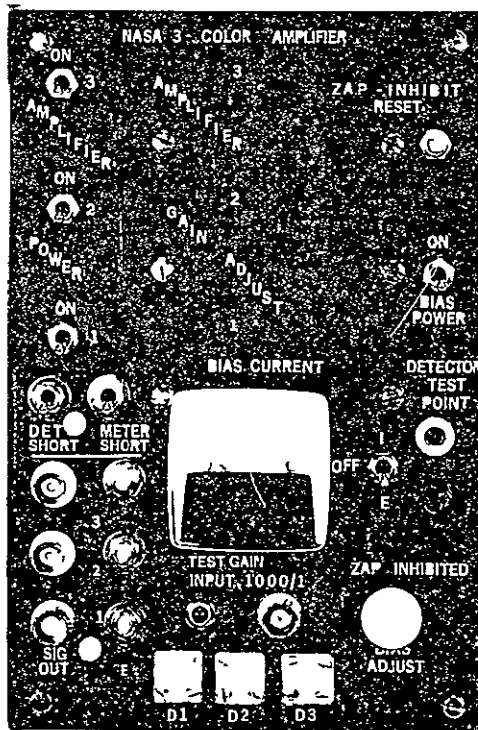


Figure E1. FRONT PANEL VIEW OF THE MODIFIED THREE-CHANNEL LOW-NOISE PREAMPLIFIER UNIT.

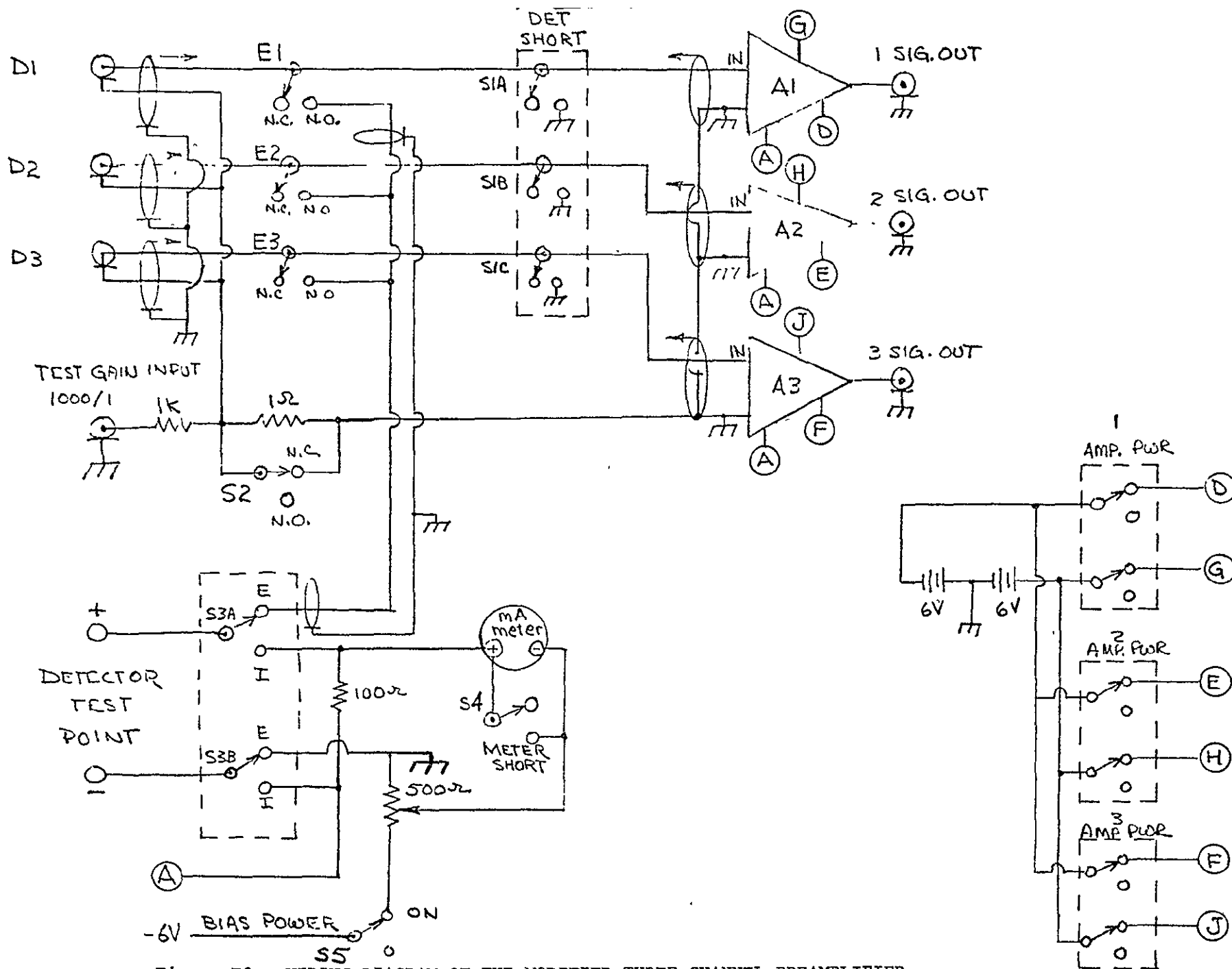


Figure E2. WIRING DIAGRAM OF THE MODIFIED THREE-CHANNEL PREAMPLIFIER

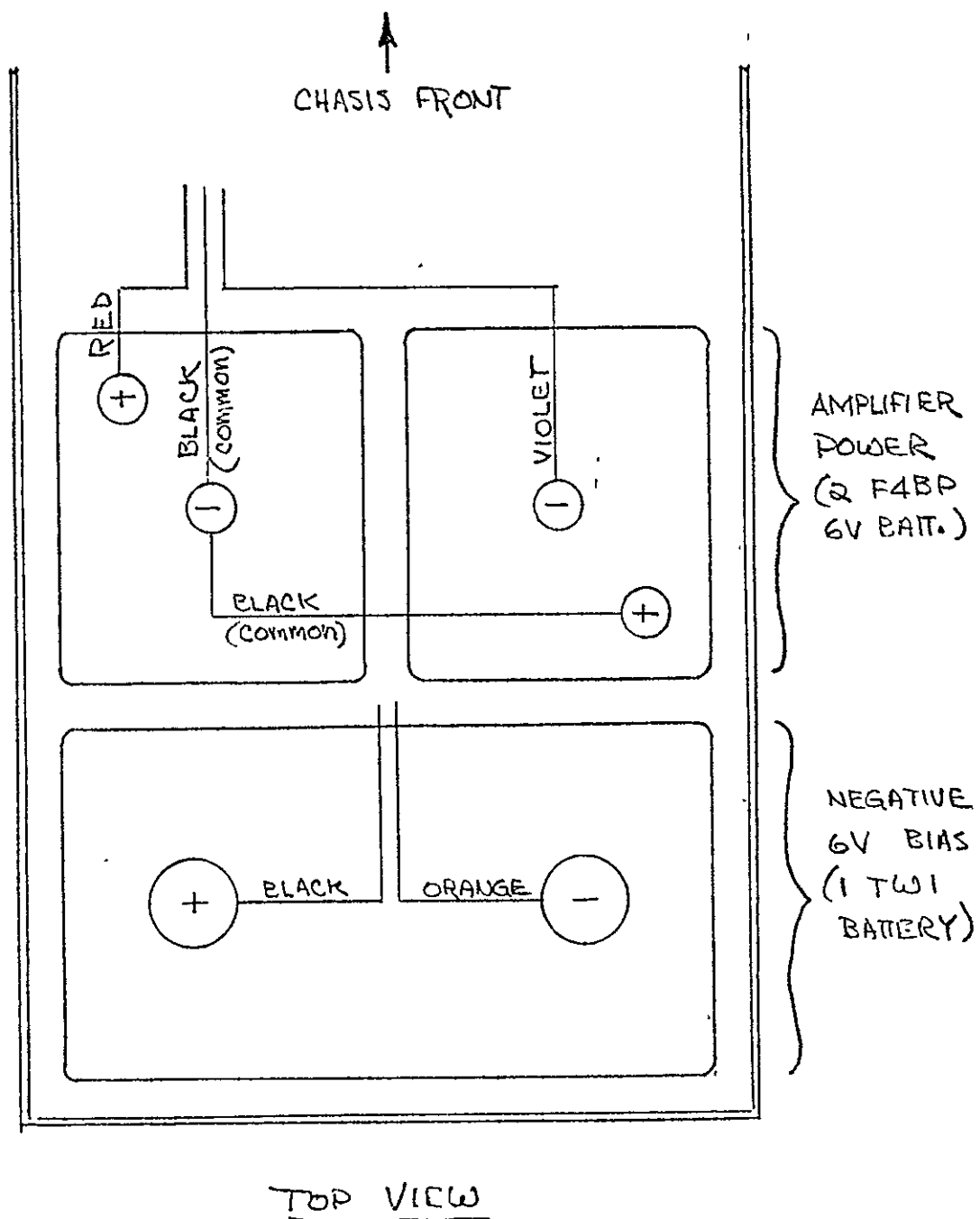


Figure E3. BATTERY WIRING ARRANGEMENT FOR THE MODIFIED THREE-CHANNEL PREAMPLIFIER.

APPENDIX F
DEWAR DRAWING AND DIMENSIONS

Figure F.1 contains drawings of the metal liquid-nitrogen dewar used for the three detector modules.

F2

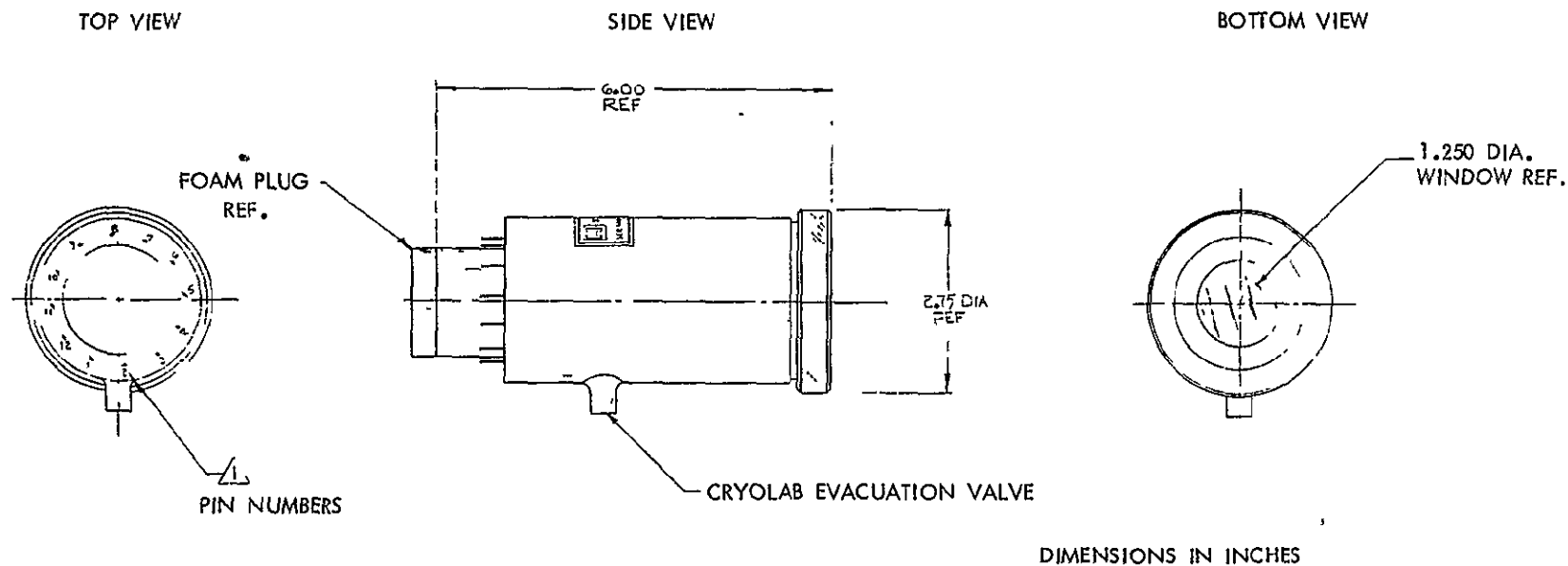


Figure F1 DRAWING AND DIMENSIONS OF THE METAL LIQUID-NITROGEN DEWARS USED FOR THE THREE DETECTOR MODULES

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